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JULY 1 - DECEMBER 31, 1965

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TO THE CONGRESS OF THE UNITED STATES:

This is a report of a period—July 1 through December 31, 1965—characterized by outstanding progress in the Nation's space program.

Manned space flights were extended to 8 and 14 days by Gemini V and Gemini VII, and rendezvous was achieved as Gemini VI-A was maneuvered to within a foot of Gemini VII in a spectacular demonstration of precision flying in space.

In space science, Mariner IV transmitted remarkably clear pictures of the surface of Mars, and communications satellites supported Gemini operations and provided channels for TV coverage of the recovery of the Gemini astronauts.

Continued to stimulate growth in the educational, industrial, and scientific competence of the Nation. Extended to the field of international affairs. Relations with other nations helped advance the cause of international peace.

The success of the Gemini flights gives encouragement to all who look forward to safety and success in conquering the hazards of space travel. We have learned that man can function effectively in space and we believe that he is capable of the lunar mission. Now, with the support of the Congress and the American people, we proceed to meet with confidence our greatest technological and managerial adventure—the exploration of the moon.



THE WHITE HOUSE,  
October 19, 1966.

Fourteenth  
**SEMIANNUAL  
REPORT TO  
CONGRESS**

JULY 1 - DECEMBER 31, 1965



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D. C. 20546

*Cover:* Gemini VI-A and VII rendezvous. Prepared by Alfred Jordan, Visual Aids Branch, Office of Administration, NASA Headquarters.

## **HUGH LATIMER DRYDEN**

**1898-1965**

### **His words reflect his vision . . .**

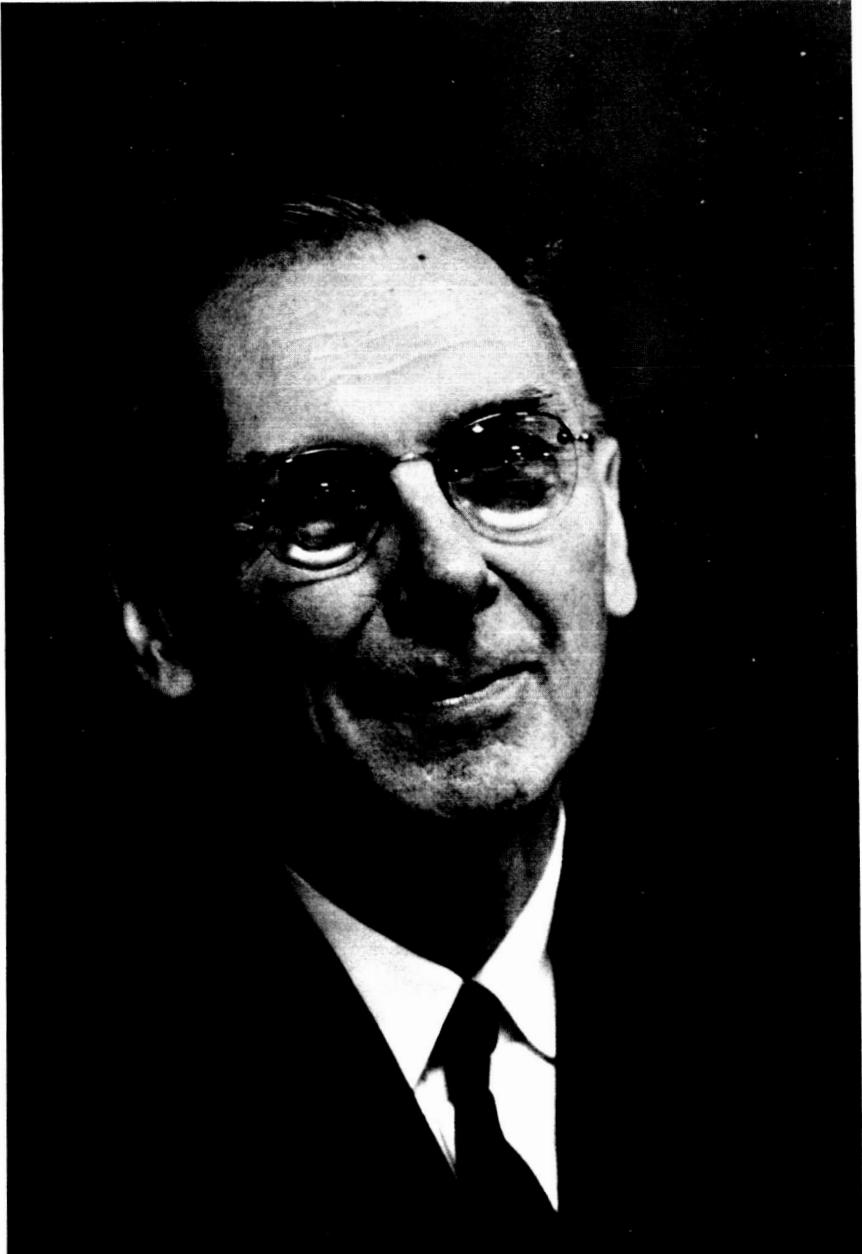
“. . . the real values and purposes are not in the mere accomplishment of man setting foot on the moon but rather in the great cooperative national effort in the development of science and technology which is stimulated by this goal . . . The national enterprise involved in the goal of manned lunar landing and return within the decade is an activity of critical impact on the future of this Nation as an industrial and military power, and as a leader of a free world.

“None of us knows what the final destiny of man may be, or if there is any end to his capacity for growth and adaptation. Wherever this venture leads us, I am convinced that the power to leave the earth—to travel where we will in space and to return at will—marks the opening of a brilliant new stage in man’s evolution.”

### **And his faith . . .**

“The horizons of our spiritual lives must be commensurate with the far horizons of our physical universe and of our intellectual and scientific accomplishment. In order to see the natural horizon around us it is necessary to rise above the ordinary level of things close to us. We must leave our ordinary surroundings and climb to the top of the hill or mountain, or better still into the atmosphere in a balloon or airplane. The higher we climb, the farther away is the horizon, and the farther we can see if the air is clear . . .

“One characteristic of many persons of our present age is the stunted development of the spiritual life and the atrophy of spiritual strength. A man of the Space Age without religious faith is incomplete, crippled, deformed, as if he had lost his sight, his hearing, or his hands.”



Dr. Hugh L. Dryden, Deputy Administrator, National Aeronautics  
and Space Administration, 1958-65

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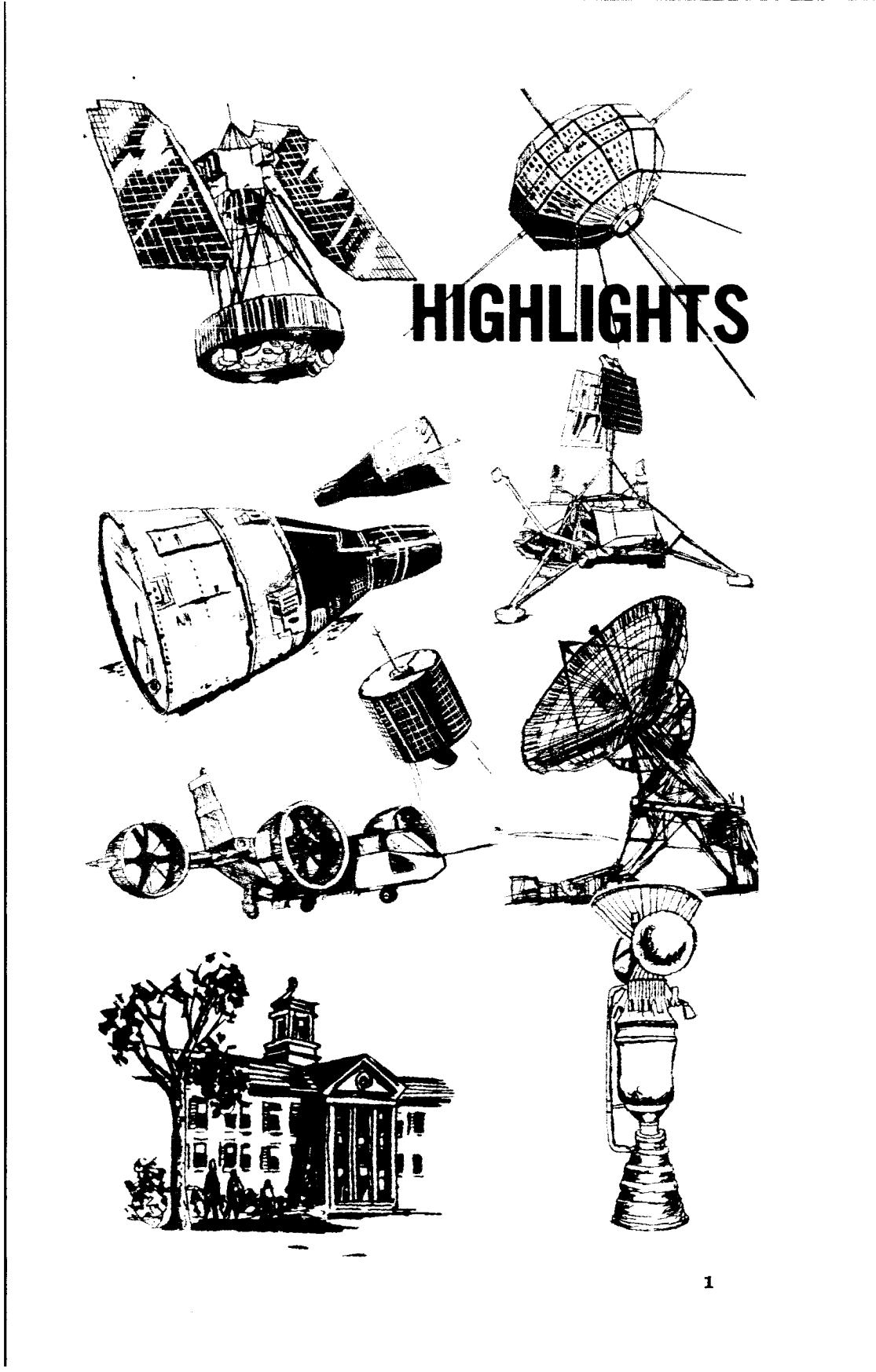
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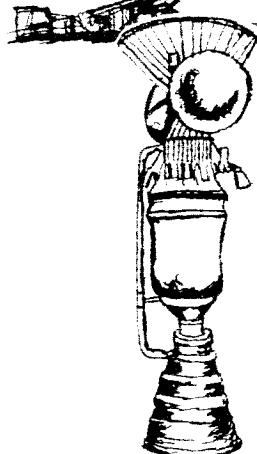
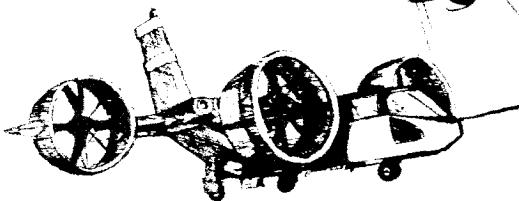
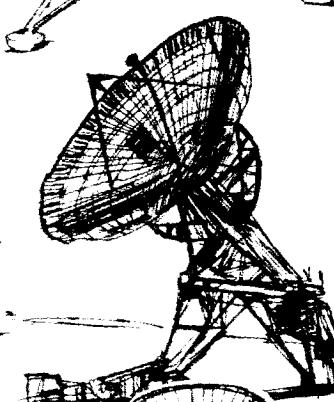
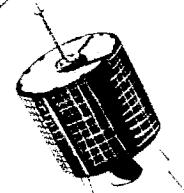
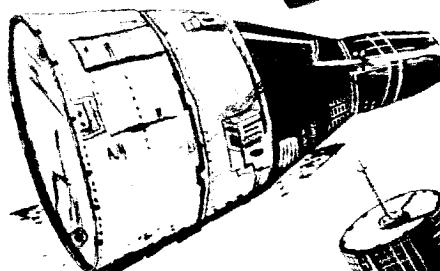
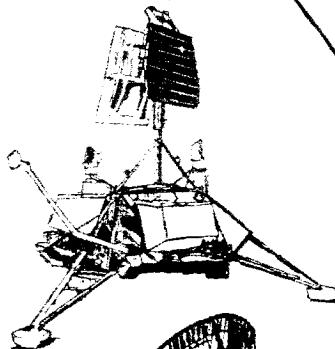
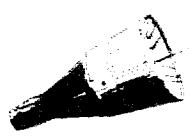
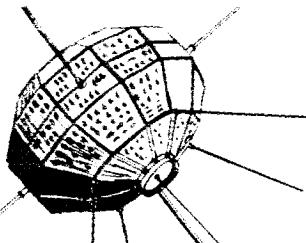
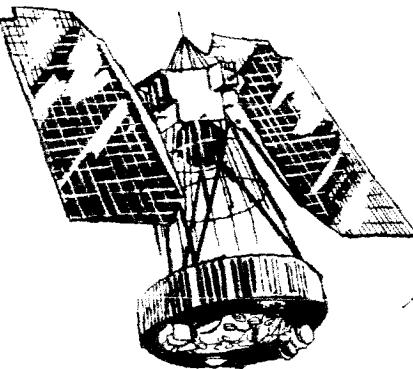
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# HIGHLIGHTS



## HIGHLIGHTS

The Gemini V mission was successfully conducted in August. The spacecraft, launched August 21, remained in orbit for 8 days—twice as long as the Gemini IV mission.

Gemini VII, launched on December 4, established a new time-in-space record of 14 days in orbit.

Gemini VI-A, launched on December 15 while Gemini VII was still in space, rendezvoused with the previously orbited spacecraft. Astronauts Schirra and Stafford, in Gemini VI-A, maneuvered their spacecraft to within 1 foot of Gemini VII, with Astronauts Borman and Lovell aboard.

Gemini V relied on fuel cells in place of batteries for electrical power, a first for the use of this power source in a manned space flight.

The Gemini VII 14-day flight, the "medical mission" of the Gemini program, carried all eight Gemini medical experiments. The results support the belief that physiologically man can withstand the rigors of a lunar mission and tend to confirm similar findings of the Gemini V flight.

The last Saturn I vehicle, launched on July 30, carried a Pegasus satellite into orbit. This launch was the 10th success in 10 tries.

More than 46,000 seconds of systems R. & D. testing of the F-1 engine were carried out by the end of December. (A cluster of five F-1 engines provides propulsion for the first stage of the Saturn V.)

The J-2 engine qualification testing was completed in December, after 1,400 tests with an accumulated ground test firing time of 90,000 seconds. Five-engine clusters of the J-2 engine (second stage of Saturn V) were also test fired.

Launch Complex 34, Kennedy Space Center, became operational during the period. This complex will be used for the uprated Saturn I launches.

•      •      •

On July 14, Mariner IV passed within 6,118 miles of Mars and televised 22 clear pictures of its heavily cratered surface.

Preparations continued for launching the 2,200-pound Surveyor I spacecraft for a soft landing on the moon. (After the close of this period, Surveyor I successfully landed on the moon—June 2, 1966—and transmitted many high-quality TV pictures of the lunar surface.)

Plans were completed for the Lunar Orbiter mission, and the first launch was scheduled for 1966.

Prints of high-quality lunar photographs supplied by Rangers VIII and IX early in 1965 were being processed and will be sent to individual scientists and institutions in the United States and overseas.

The Pioneer VI launching on December 16 inaugurated a program to investigate interplanetary phenomena during a complete solar cycle. The spacecraft, first in a series of four, is designed to send back data from distances up to 50 million miles from the earth.

Five Explorer-class scientific satellites were launched—two to determine the earth's size, shape, mass, and variations in gravity; the Canadian Alouette II in a dual launch with a NASA spacecraft to make simultaneous in-flight studies of ionospheric phenomena; and the French-built FR-1 to measure very low frequency radiation propagation and electron density.

An Orbiting Geophysical Observatory carrying 20 experiments was launched and an Orbiting Astronomical Observatory was being prepared for launch in 1966.

The Agency scheduled its first Biosatellite for launching in the fall of 1966. In a 3-day flight, this orbiting biological laboratory will investigate the effects of outer space on plants, animals, and other life forms to determine the hazards for astronauts during prolonged space missions.

Photographs of the earth and its weather taken by Project Gemini astronauts were being studied by geologists, oceanographers, meteorologists, and other scientists.

• • •

Four orbiting TIROS meteorological satellites made possible uninterrupted use of satellite data for operational purposes. In August, TIROS X warned of a hurricane near the planned recovery area of Gemini V; the flight was therefore terminated one orbit earlier to avoid the storm area.

Photographs from the more advanced meteorological satellite, Nimbus I, revealed marked changes in the map of Antarctica. A second Nimbus spacecraft to observe the earth's heat balance was being prepared for a 1966 launch. (This satellite was successfully orbited on May 15, 1966.)

Early Bird, the first commercial communications satellite of the Communications Satellite Corp., made possible live December telecasts of the Gemini VI-A and VII spacecraft recoveries from the deck of an aircraft carrier.

Another communications satellite, Syncom III—used by the Defense

Department for transmissions between the United States and the Far East—was part of the communications network for the Gemini V flight in August.

Assembly of the prototype model of the spin-stabilized Applications Technology Satellite began, with launching scheduled for late 1966.

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The Pegasus III Meteoroid Technology Satellite, launched July 30, has returned useful data on the near-earth meteoroid environment.

The HL-10, one of the two NASA lifting body research vehicles, was completed and prepared for delivery. The M-2, the other vehicle, after wind tunnel tests and preflight checkout, was approved for flight.

Fire II, the reentry heating experiment flown on May 22, gave very accurate data on the heat load borne by an Apollo-type vehicle entering the atmosphere at lunar return speeds.

The three X-15 research aircraft were used for a wide variety of investigations, making a total of 18 flights during the period.

The second XB-70 aircraft entered the SST flight research program, making its first flight during the period. Both aircraft collected data on the sonic boom and on operating, structural, and other problems.

The 260-inch solid motor was successfully test fired on September 25, producing a peak thrust level of 3½ million pounds.

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A 2,000-hour endurance test of a two-stage potassium vapor turbine was completed in late December; the post test inspection showed little erosion damage.

A boiling potassium corrosion loop made of an advanced columbium-base alloy successfully completed a 5,000-hour test.

A gas-bearing-supported, radial flow turbocompressor was delivered to NASA and at the end of the period was being installed in Lewis facilities for "hot gas" testing.

An isotopically fueled generator, the SNAP-27, was selected to power the Apollo Lunar Surface Experiment Package.

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During the Gemini VII/Gemini VI-A flights, the Manned Space Flight Network simultaneously tracked and maintained communications with the two spacecraft and the four astronauts in real-time.

Construction of facilities to support the Apollo program was completed at Guam; Carnarvon, Australia; Bermuda; Cape Kennedy; Hawaii; Guaymas, Mexico; and Ascension Island.

Construction continued on the five instrumentation ships which will provide tracking, communication, telemetry, navigation, and data processing facilities for the Apollo program.

A contractor was selected to modify and instrument eight C-135 jet aircraft; these will be used in the Apollo program for voice and telemetry transmission from the spacecraft to the ground network.

Deep Space Network facilities at Goldstone and Pasadena, Calif., received the Mariner IV transmissions of 22 photographs of Mars.

In December, the network received signals transmitted from Mariner IV when it was 20 million miles away (a one-way record).

The Deep Space Network supported the Pioneer VI mission, launched December 16.

The Satellite Network supported 50 satellite programs, 11 of which were launched during the year (including 3 DOD satellites).

A new 85-foot antenna at Canberra, Australia, became operational in September, rounding out the prime support for the Orbiting Geophysical Observatory (OGO) program.

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As part of a NASA-CNAE (Brazilian National Space Commission) cooperative project, three sounding rockets were launched (two from the Barreira do Inferno range near Natal, Brazil, and one from Wallops Island).

NASA and CNAE also agreed on two other cooperative sounding rocket projects.

Under its cooperative program with Canada, NASA launched the ISIS-X payload (Canadian Alouette II and the NASA Direct Measurement Explorer-A spacecraft).

The FR-1, first cooperative satellite with France, was launched December 6.

More than 2,500 foreign nationals from 112 locations visited NASA centers during the period.

Twenty-five graduate students (under the NASA international university fellowship program) completed their studies; 50 others either entered the program or continued their studies.

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In September, 1,275 new students began studies under the sustaining university program. This made a total of 3,132 trainees engaged in full-time work for the doctorate at 142 universities.

One hundred fifty-two institutions were selected for the fiscal year 1966 training program; 10 of these were participating for the first time.

The summer faculty fellowship program provided training for about 100 faculty members with the cooperation of 12 universities and 7 NASA field centers.

Summer institutes for outstanding undergraduates were held at 3 locations, offering 6 weeks of training in space science and technology to about 140 senior students.

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Support was provided for multidisciplinary space-related research at 36 educational institutions; grants for new programs were awarded 3 institutions. Facilities grants were awarded 5 institutions; 2 universities initiated work—making a total of 10 projects under construction—and 6 NASA-supported facilities were completed.

NASA's informational-educational programs provided exhibits on the space program for more than 8.5 million viewers at a unit cost of about 3 cents a viewer.

Over 32,000 requests for educational publications and 3,100 for motion pictures were answered, and a *Dictionary of Technical Terms for Aerospace Use* and a *Sourcebook on the Space Sciences* were released.

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Special spacemobile programs supplied information on space science and exploration to students in culturally deprived areas in Philadelphia, Pasadena, and Boston. In cooperation with Howard University, NASA instituted a series of lectures for adult culturally deprived groups in New York City, suburban Jacksonville, Fla., and rural Cheneyville, La.

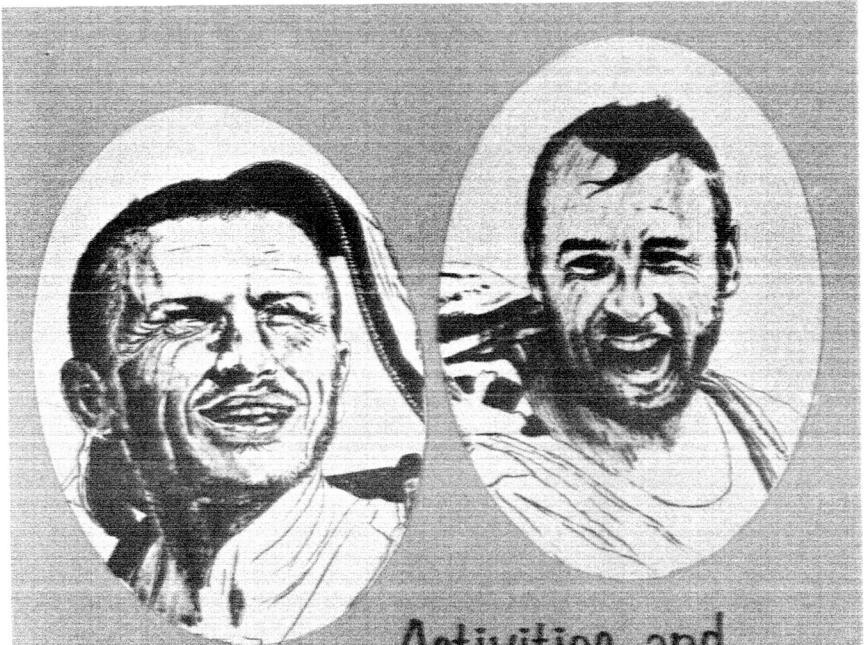
An estimated 77 million persons saw NASA's educational TV documentaries and other telecasts, and over 2,000 radio stations broadcast the Agency's weekly 5-minute "Space Story" program.

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More than 950 NASA personnel participated in such training courses as procurement management, incentive contracting, contract cost management, and PERT seminars.

Dr. Robert C. Seamans was appointed Deputy Administrator of NASA, succeeding the late Dr. Hugh L. Dryden.

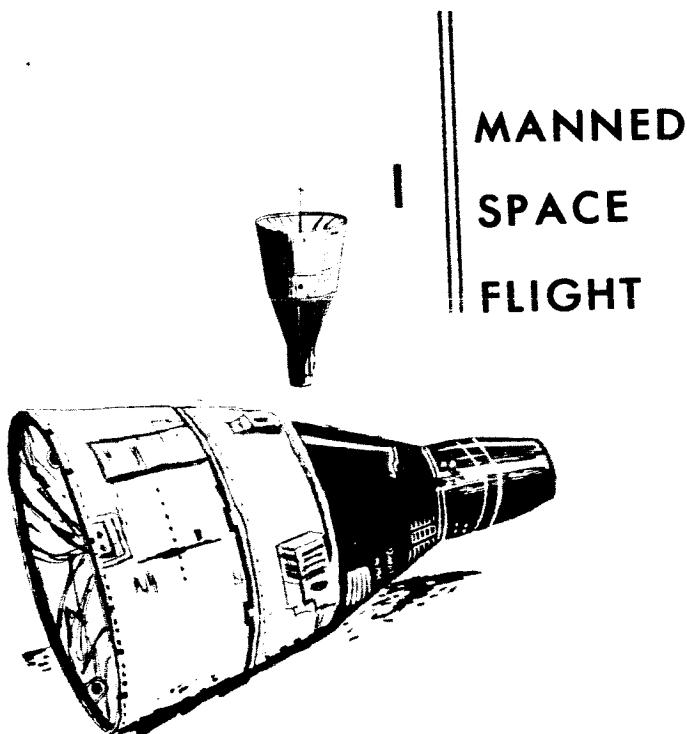
Eighty-eight NASA employees received a total of \$27,100 for inventions on which patent applications were filed by the Agency.



## Activities and Accomplishments



Gemini VI-A and VII astronauts (clockwise from top right)  
Lovell, Schirra, Stafford, and Borman. Prepared by NASA  
artist Alfred Jordan.



## MANNED SPACE FLIGHT

During the period covered by this report, NASA's manned space flight activities made significant progress, with three successful manned space missions in the Gemini program, completion of the Saturn I flights and further gains in the development of the uprated Saturn I and Saturn V launch vehicles, advancements in the development and fabrication of the Apollo spacecraft, and the construction/activation of essential support facilities.

Management of the manned space flight program continued being improved, with certain organizational refinements designed to obtain the best use of the capabilities of the people, the ground facilities, and the flight equipment. The Office of the Associate Administrator for Manned Space Flight was strengthened by the appointment of a general deputy who is concerned with relationships between the field centers and the Office of Manned Space Flight.

The Agency gave increased time and attention to planning for future manned space flight efforts. Toward this end a new organization, the Saturn-Apollo Applications Office, was established in August. This office is responsible for the direction of activities that may make use, for purposes other than the current Apollo program, of the Saturn launch vehicles and the Apollo spacecraft. At period's end, this office

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was engaged in defining Apollo applications based on maximum use of both the Gemini system and the Apollo capabilities.

In another effort to improve the management of its manned space flight activities, NASA established the Operations Executive Group. Members of the group are senior executives of NASA, of the Department of Defense, and of industry whose organizations are significantly involved in manned space flight operations. The purpose of the group is to strengthen the interface between operational elements and to familiarize these executives with manned space flight objectives and the anticipated problems in achieving them. The group will meet periodically to review results of completed missions and to provide policy guidance as appropriate for current and forecast operational problems.

As an auxiliary to the Operations Executive Group, the Agency also established an Operations Management Group, made up of operating management officials within NASA and DOD. This group is expected to convene as required to conduct postflight critiques and to resolve operating problems.

As mentioned in the previous (13th) *Semiannual Report*, NASA entered into a cooperative arrangement with the Air Force to obtain 128 trained military personnel to perform flight operations functions at the Manned Spacecraft Center. These individuals are being utilized to fulfill part of NASA's requirement for personnel to handle operations-oriented functions. Also, NASA was in the process of transferring 200 positions from the Marshall Space Flight Center to the Manned Spacecraft Center in preparation for the Apollo missions.

### The Gemini Program

In three manned flights during this period, the Gemini program contributed to the major objectives of manned space flight and advanced this Nation's capability to perform useful tasks in space.

In August, the second long-duration mission, Gemini V, proved that men could function effectively in space for 8 days. In December, the 14-day Gemini VII mission was accomplished successfully. Concurrent with the Gemini VII mission, the rescheduled Gemini VI (designated Gemini VI-A) was conducted. The Gemini VI-A was launched 11 days after Gemini VII and rendezvoused with that spacecraft on December 15. This was the first successful rendezvous of two spacecraft in space, a major milestone for the U.S. manned space flight program.

During this period the investigation of long-duration flight, a major program objective, was completed. The Gemini VII 14-day mission

demonstrated that man can perform effectively during long periods of orbital flight and validated the life-support technology that is being developed in our manned programs.

### Gemini V

The third manned Gemini mission, Gemini V, was launched on August 21, 1965, within 11 weeks of Gemini IV. (Fig. 1-1.) Gemini V, 8 days in duration, was the second of three long-duration missions conducted in 1965. This mission demonstrated from a medical and crew standpoint the feasibility of the Apollo lunar mission which requires 7 or 8 days to land on the lunar surface and return. A major technical achievement of this mission was the use of fuel cells in lieu of batteries as the primary electrical power supply for the spacecraft. Fuel cells produce electrical energy by chemically reacting hydrogen and oxygen in the presence of a catalyst. Early in the mission, a drop in pressure of the oxygen tank supplying the fuel cell occurred because of a malfunction in the tank's heater circuitry. The fuel cell, however, continued to work well.

The Gemini V mission demonstrated the spacecraft weight that can be saved by using fuel cells as a power source. (Fig. 1-2.) The Gemini V spacecraft fuel cell installation including the hydrogen and oxygen supply weighed about 600 pounds. If Gemini had used batteries, spacecraft weight would have increased approximately a thousand pounds. The Gemini fuel cell will be used in NASA's biosatellite program and similar fuel cells will be utilized in the Apollo Command and Service Module as the primary power source.

Seventeen scientific, medical, technological, and engineering experiments were planned for Gemini V and 16 were successfully conducted. The results of these experiments along with the results of the Geminis VI-A and VII experiments will be published for public dissemination as a major part of the proceedings of the Gemini midprogram review scheduled for February 1966. The medical results of Geminis V and VII are described in another section of this report.

### Gemini VII

The fourth manned mission of the Gemini program was launched on December 4, 1965. The successful completion of this mission 14 days after launching was the final vital step in the attainment of the long duration objective of the Gemini program. Gemini VII demonstrated that man can operate and perform useful functions in orbit for extended time periods and significantly increased medical confidence in the feasibility of manned orbital flight in excess of thirty days.

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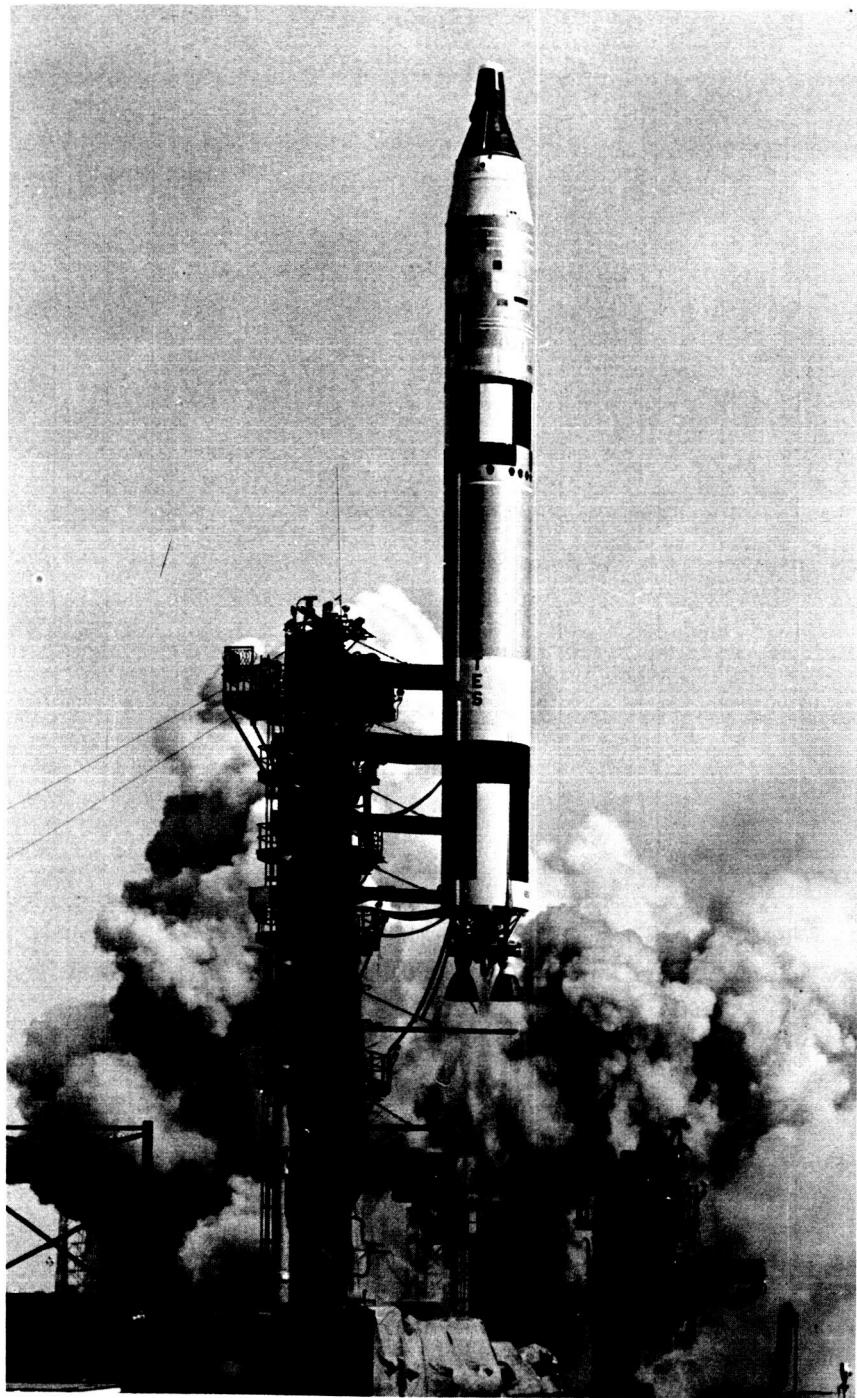


Figure I-1. Gemini V launch, August 21, 1965.

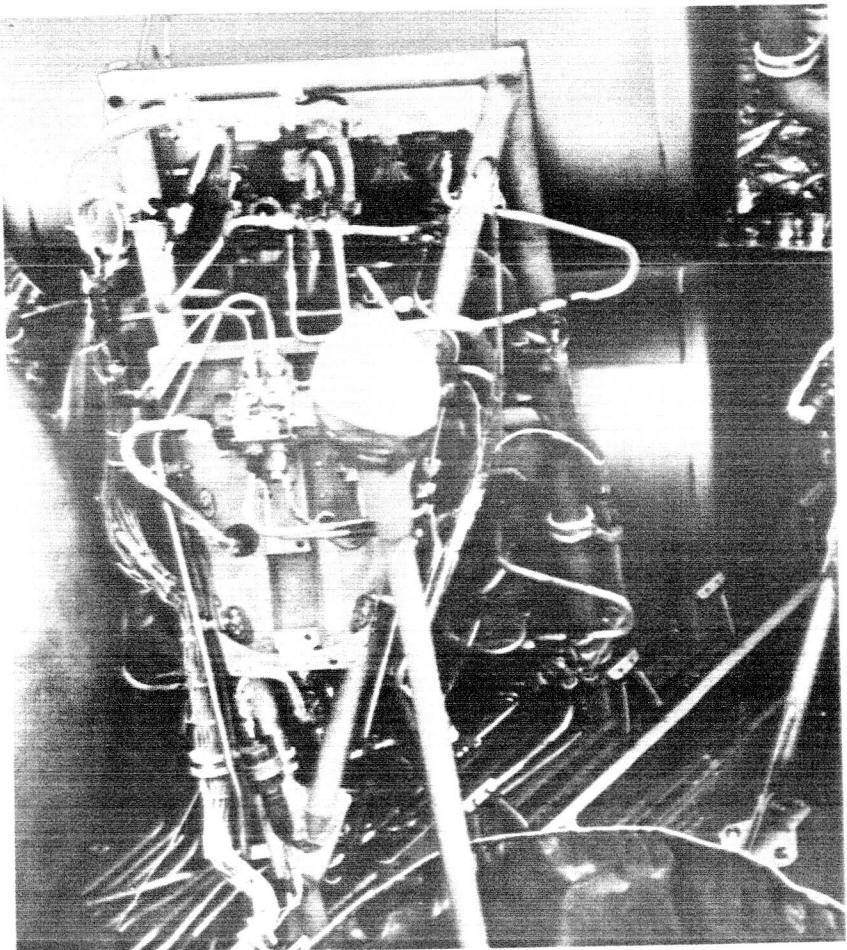


Figure 1-2. Fuel cell like that aboard Gemini V.

As in Gemini V, a large number of experiments were planned for Gemini VII. During the mission, 18 of the planned 20 experiments were executed. Both astronauts wore a new lightweight pressure suit for this mission that provided a major improvement in comfort and mobility over previous suits. Both crewmembers removed their suits during certain time periods of the mission and worked in a shirt-sleeve environment. The fuel cell power system met all mission requirements and demonstrated for the second time in the Gemini program its value as a spacecraft power source. A controlled reentry was flown and the spacecraft landed within 7 miles of the planned landing point. Overall spacecraft systems performance during the

mission was excellent. Four years of extensive development, testing, and production efforts to meet the stringent performance requirements of a 14-day orbital mission were culminated by the successful completion of the Gemini VII mission.

### Gemini VI-A

The Gemini VI mission, the first rendezvous mission in the Gemini series, was first attempted on October 25, 1965. The simultaneous countdown for the Atlas-Agena and the Gemini launch vehicle and spacecraft continued through the Agena launch at 10 a.m., e.s.t., as shown in figure 1-3. The mission was terminated within the hour because the Agena target vehicle failed to achieve orbit. It was determined later that a severe hard start of the Agena engine resulted in a premature engine shutdown, the propellant tanks burst and the vehicle was destroyed. An intensive investigation, analysis, and test program was instituted by NASA and the USAF to determine the cause for the hard start and corrective action required. This effort has continued through the end of the year and will be completed in March 1966, in time for the second rendezvous mission, Gemini VIII.

Because of the Agena failure an alternate plan for rendezvous was activated in order to utilize the extensive planning and preparation that had been accomplished for Gemini VI. The plan was to launch Gemini VII and use it as a rendezvous target for Gemini VI (re-designated VI-A). This type of planning was feasible because the Gemini VI space vehicle had been completely checked out and counted down to within an hour of launch, and required minimum rechecking before launching it as Gemini VI-A. Additionally, the level of training, experience, and proficiency of the launch operations and flight operations personnel in Gemini provided the flexibility and capability to accommodate the new mission plan. This proficiency in all phases of launch and flight operations is another major contribution of Gemini to the manned space flight program.

After a normal countdown for a scheduled liftoff on December 12, the Gemini VI-A launch vehicle ignition occurred, but was terminated 1.19 seconds later. The immediate cause was the premature separation of a pad liftoff disconnect tailplug. Subsequent data analysis revealed that ignition would also have been terminated before liftoff because of a difference in thrust buildup between the two first-stage engine assemblies. The launch vehicle, pad, and umbilical tower were refurbished in record time and on December 15 the Gemini VI-A spacecraft and launch vehicle were successfully launched from Complex 19 within one-tenth of a second of the planned time for launch,

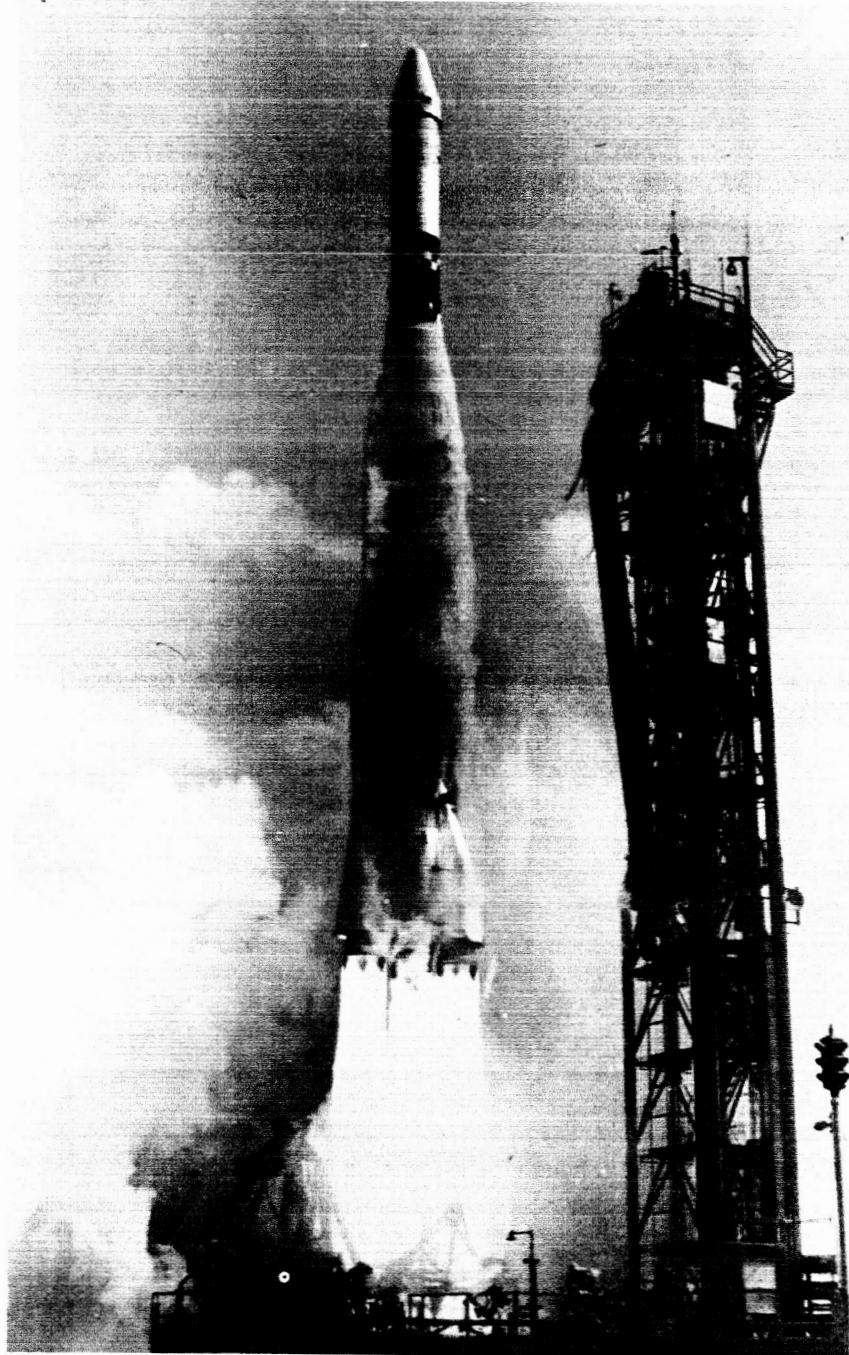


Figure 1-3. Launch of Atlas-Agena target, October 25, 1965.

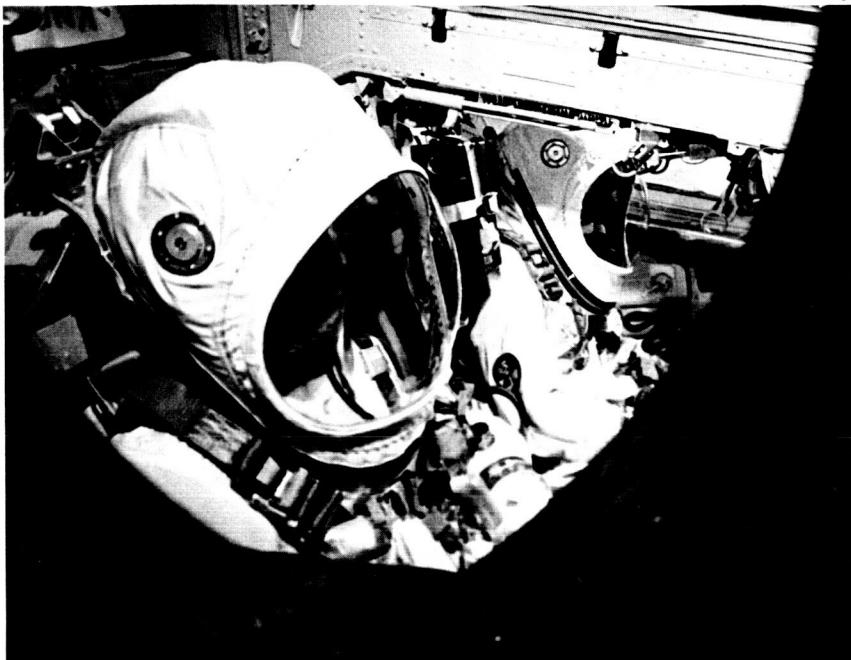


Figure I-4. Astronauts Borman and Lovell in Gemini VII.

11 days after Gemini VII was launched from Complex 19. Five hours and 56 minutes later the first successful rendezvous by two spacecraft was accomplished when Gemini VI-A maneuvered to within 120 feet of Gemini VII. For 3½ orbits after the rendezvous Gemini VI-A and VII conducted stationkeeping maneuvers at distances that varied from 1 foot to 300 feet.

The high performance and sensitive control characteristics of the spacecraft Orbit Attitude and Maneuvering System were vividly demonstrated during the rendezvous and stationkeeping maneuvers by Gemini VI-A. The rendezvous radar performed exceptionally well from the time it locked on Gemini VII at 248 miles until it was turned off at a distance of 50 feet from Gemini VII. Three experiments were successfully conducted during the flight. Gemini VI-A flew a controlled reentry and landed within 7 miles of the planned landing point. The high degree of accuracy in controlled reentry attained by Geminis VI-A and VII was another indicator of the proficiency in flight operations developed in Gemini in 1965. (Illustrations 1-4 through 1-12 depict the Geminis VII and VI-A missions.)

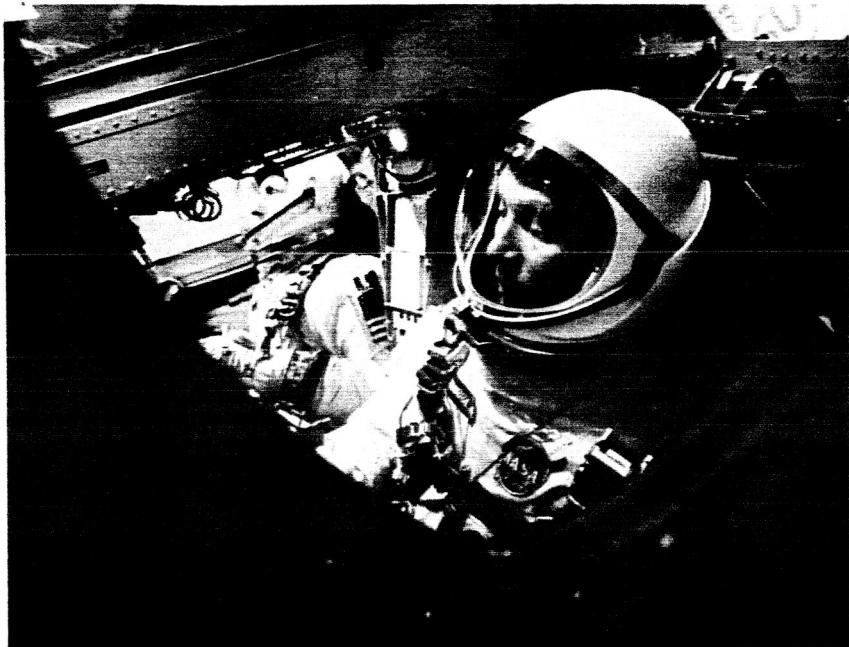


Figure 1-5. Astronauts Schirra and Stafford in Gemini VI-A.

### Development, Production, and Test

The Gemini space vehicle consists of a spacecraft and a modified Titan II launch vehicle. The target vehicle used for a rendezvous mission consists of an Atlas Standard Launch Vehicle (SLV-3) and the Gemini-Agena target vehicle. These major elements have completed their development and qualification phases and are well into their production phase.

#### Spacecraft

Spacecrafts VI and VII were delivered to Cape Kennedy during this period. Spacecraft VIII completed systems test and was to be delivered in January 1966. Spacecraft IX was in assembled systems test. Spacecrafts X, XI, and XII were in final stages of manufacture and assembly.

#### Gemini Launch Vehicle

Delivery of Gemini Launch Vehicle (GLV) 6 was completed in August 1965. GLV 7 was delivered in October and delivery of GLV 8 will be completed in January 1966. GLV 9 was in systems test in the Vertical Test Facility, GLV 10 was in horizontal test, and GLV's 11 and 12 were in final stages of manufacture and assembly.

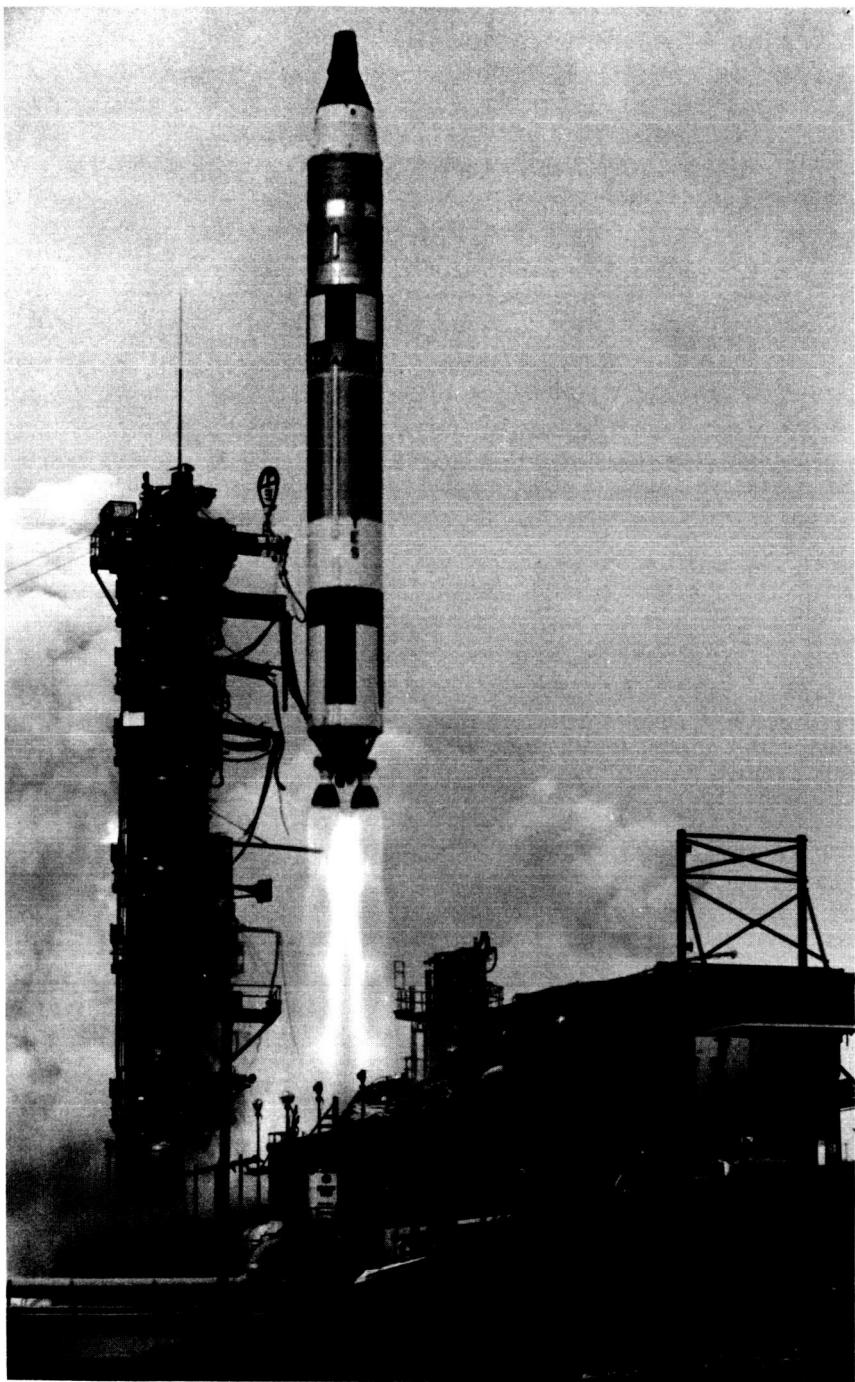


Figure 1-6. Launch of Gemini VII.

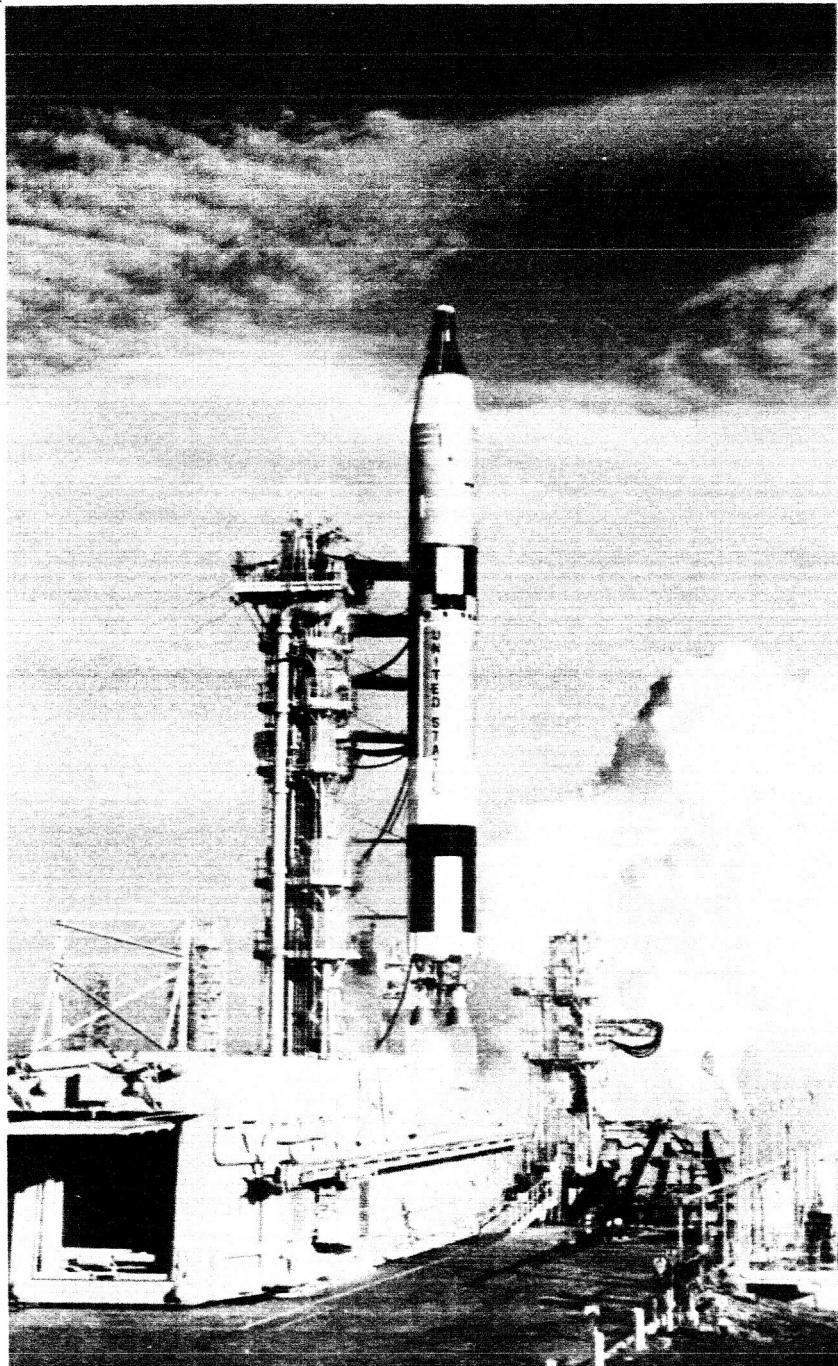


Figure I-7. Launch of Gemini VI-A.

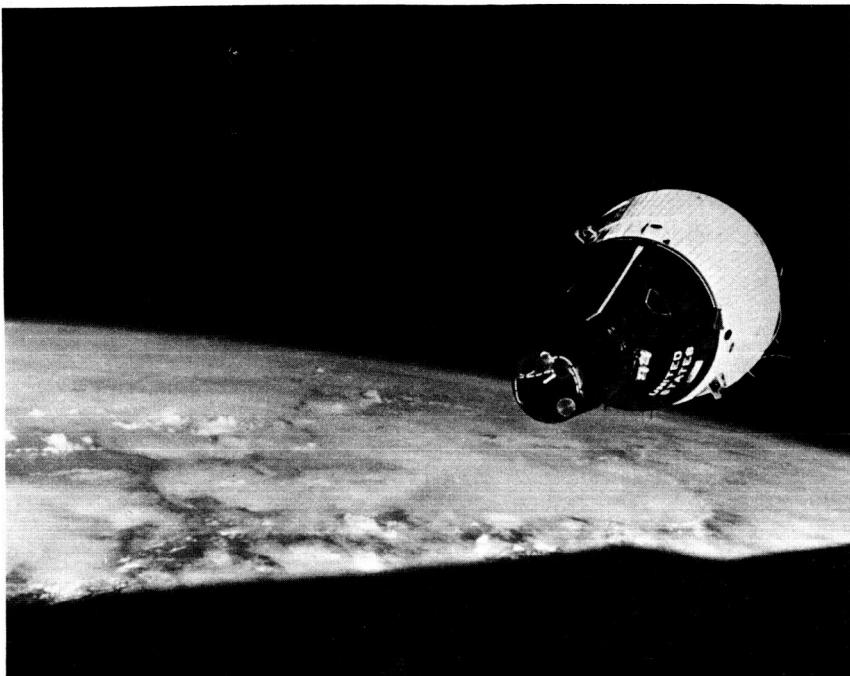


Figure I-8. Gemini VII photographed from distance by Gemini VI-A crew.

#### Atlas SLV-3

The Atlas launch vehicle for Gemini VIII (Atlas 5302) was delivered in August 1965. Atlas 5303 for Gemini IX is to be delivered in February 1966. Atlas 5304 was in final assembly, and 5305 and 5306 were in various stages of manufacturing.

#### Agena Target Vehicle

Agena 5002 was delivered to Cape Kennedy in July 1965. Agena 5003 was scheduled for delivery in January 1966. The basic Agena D for Agena 5004 was accepted by NASA from USAF in October 1965. The basic Agena D for Agena 5005 was midway through manufacturing and Agena 5006 manufacturing has started.

#### Augmented Target Docking Adapter (ATDA)

To provide a backup for the Agena target vehicle, an Augmented Target Docking Adapter has been added to the Gemini program. This vehicle was being manufactured by the Gemini spacecraft manufacturer, and was to be delivered in February 1966. All of its critical components are qualified spacecraft components presently available in the Gemini inventory. In the event of another Agena failure or

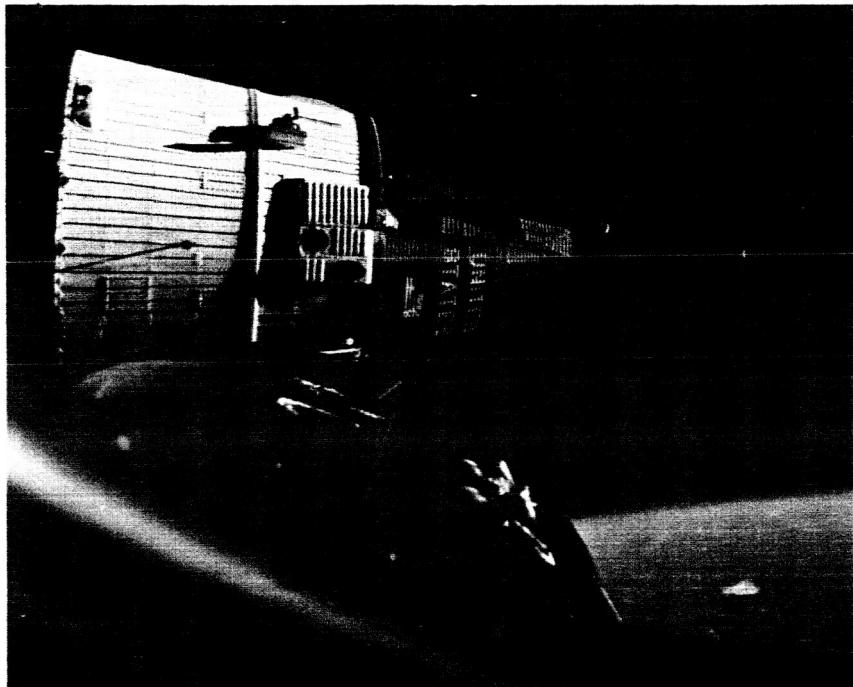


Figure I-9. Closeup of Gemini VII, taken from Gemini VI-A.

serious schedule delay this vehicle will be used as a rendezvous and docking target for the spacecraft.

#### **Experiments Symposium**

The first Gemini Experiments Symposium was held in Washington, D.C., on October 18 and 19, 1965. The object of this symposium was to disseminate as widely as practicable to the Nation's scientific community the results of experiments conducted on Gemini missions III and IV.

Another symposium will be held in January 1966 on experiments conducted on the Gemini V mission. An overall review of Gemini experiments results will be presented in conjunction with the Gemini Midprogram Conference.

#### **Gemini Midprogram Conference**

A 3-day Gemini Midprogram Conference will be held at the Manned Spacecraft Center in Houston beginning on February 23, 1966. Administrative and operational achievements that have contributed to the Gemini success to date will be presented. A broad segment of Government, industry, and the scientific community will attend the

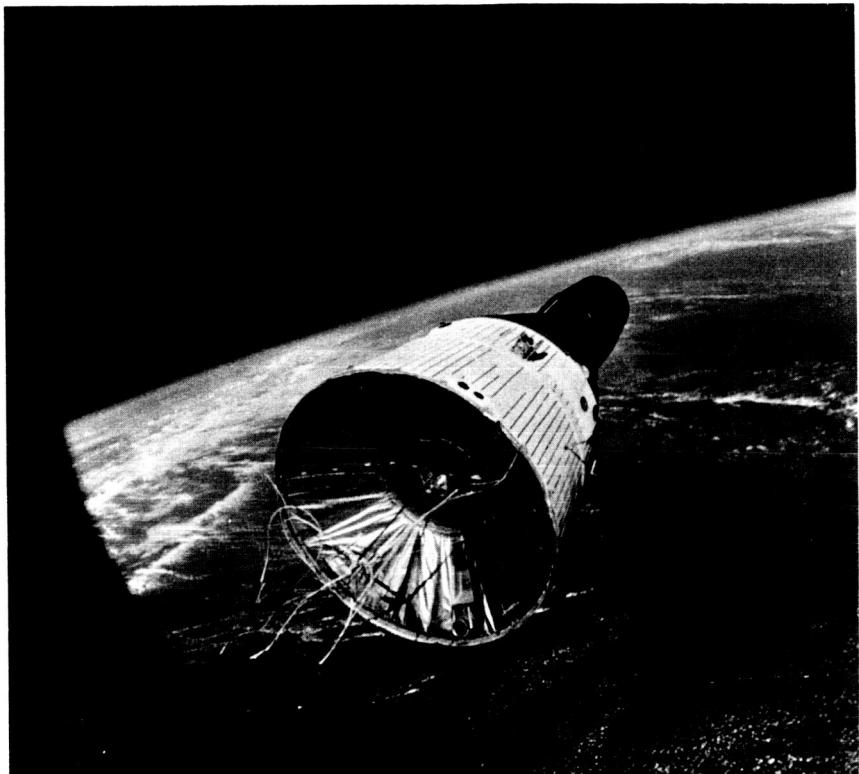


Figure I-10. Gemini VII photographed as Gemini VI-A moves away following rendezvous.

conference. This will be the first of two such conferences and will mark the successful attainment of the long-duration flight objectives. The second and final conference will be held in early 1967 following completion of the program.

#### Medical Results of Gemini

The Gemini VII flight, the "Medical Mission" of the Gemini series, was the first to carry all of the eight Gemini medical experiments. Because of the time span of Gemini VII, the medical results were significantly more important than the findings obtained from previous flights in the series. Also, in addition to the greater number of medical experiments on board, preparation for the flight provided for longer and more demanding periods of baseline studies than ever before.

The 14-day flight indicated that there is very little likelihood of any physiological barrier to a manned lunar mission. The medical conclusion that man can be supported in long-duration orbital flights



Figure 1-11. Gemini VI-A after splashdown.



Figure 1-12. Gemini VII astronauts aboard carrier.

without any major changes in life-support techniques was justified by this mission.

Throughout the flight, the physical condition and the psychological adjustment of the crew were excellent. Blood pressures and heart rates remained within normal ranges during the various phases of launch, rendezvous with Gemini VI-A, and reentry. Postflight tests on a bicycle ergometer showed only little differences in work capacity from similar tests conducted prior to flight. Postflight tilt-table studies, which provide some quantitative measure of the effect of zero gravity on cardiovascular system adaptability, revealed changes that were no different in character from those observed in shorter flights.

Gemini VII therefore showed that man is both physically and psychologically able to function adequately through 14 days in space, thus assuring the feasibility of the Apollo earth-orbital missions. The flight also provided a reasonable basis for predicting that man can endure in space for periods considerably beyond the 14 days achieved thus far.

Earlier in the reporting period, in August, the 8-day flight of Gemini V occurred. This flight was significant medically because it demonstrated the physiological capability of man to undertake the lunar mission, a conclusion which was confirmed and strengthened by Gemini VII some 3 months later. The medical results of this flight were completely satisfactory. Physiological data obtained during the course of the mission remained within normal and predicted limits, and no unexpected physical effects were observed in postflight examinations. The same general pattern of results applied to Gemini VI-A as well. Thus, in the three manned space flights in the latter half of 1965 no medical operational information was acquired which could be considered to compromise the crews' ability to function during the in-flight or postflight phases of the missions.

The program of operational medical information acquisition is concerned with the safety and welfare of space crews during a flight mission. It emphasizes symptoms or overt manifestations of dysfunction, since any appearance of these would indicate the need for medical response during the flight.

### **The Apollo Program**

In the Apollo program, the extensive and intensive test program initiated during the previous report period reached maturity in the last half of 1965. Thousands of tests were performed on equipment ranging from the smallest part to the complete space vehicle. Development and qualification tests of spacecraft modules, launch vehicle stages, and supporting equipment were successfully conducted to as-

sure the reliability of Apollo components being readied for upcoming flight testing. The flight test phase of the Apollo program will begin early in 1966.

### **Spacecraft**

The Apollo Command and Service Module spacecraft ground test program continued, with the use of two distinct types of test hardware: boilerplate and airframes. The boilerplate test article, though heavier, has the same external size, shape, and center of gravity as the airframe; the instrumentation and subsystems aboard the boilerplate will vary depending upon the test mission.

The boilerplate spacecraft testing was nearing completion while testing of the flight-weight airframe spacecraft was underway. Airframe testing was conducted to verify the structural design of the spacecraft and the operating characteristics of the subsystems before flight.

The airframe ground test program is being conducted in two phases. The Block I ground test program is expected to verify the earth-orbital Command and Service Module (CSM) configuration that will be flown on four of the first six Saturn IB flights and on the first two Saturn V flights. The Block II ground test program is expected to verify the Command and Service Module that will be used with the Lunar Module during earth-orbital flights and the lunar mission.

Test firing on Airframe 001 (of flight weight design) which began in the first half of 1965 at the White Sands Test Facility, continued throughout the report period. (Fig. 1-13.) Testing included system checkout runs; engine starts, restarts, and shutdowns; the CSM-009 mission duty cycle; and several runs of the CSM-011 mission duty cycle. Runs were made with varied engine mixture ratio, with high and low chamber pressure, with propellants conditioned hot or cold, and with the Service Module engine being gimballed.

A most significant accomplishment of Airframe 001 testing was completion of the tests necessary for the support of the CSM-009 mission. As the payload for the SA-201 launch vehicle in the first launch of the Apollo uprated Saturn I (Saturn IB) space vehicle early in 1966, CSM-009 was a focal point of activity during the report period.

Factory checkout tests of Airframe 011 (CSM-011) began in November at the North American Aviation plant to place this spacecraft in readiness for the second Apollo uprated Saturn I flight in 1966. A boilerplate spacecraft (No. 14) was used in support of those tests.

Another flight spacecraft (CSM-008) was in systems installation. This vehicle will be used in the critical thermovacuum testing program at the Manned Spacecraft Center.

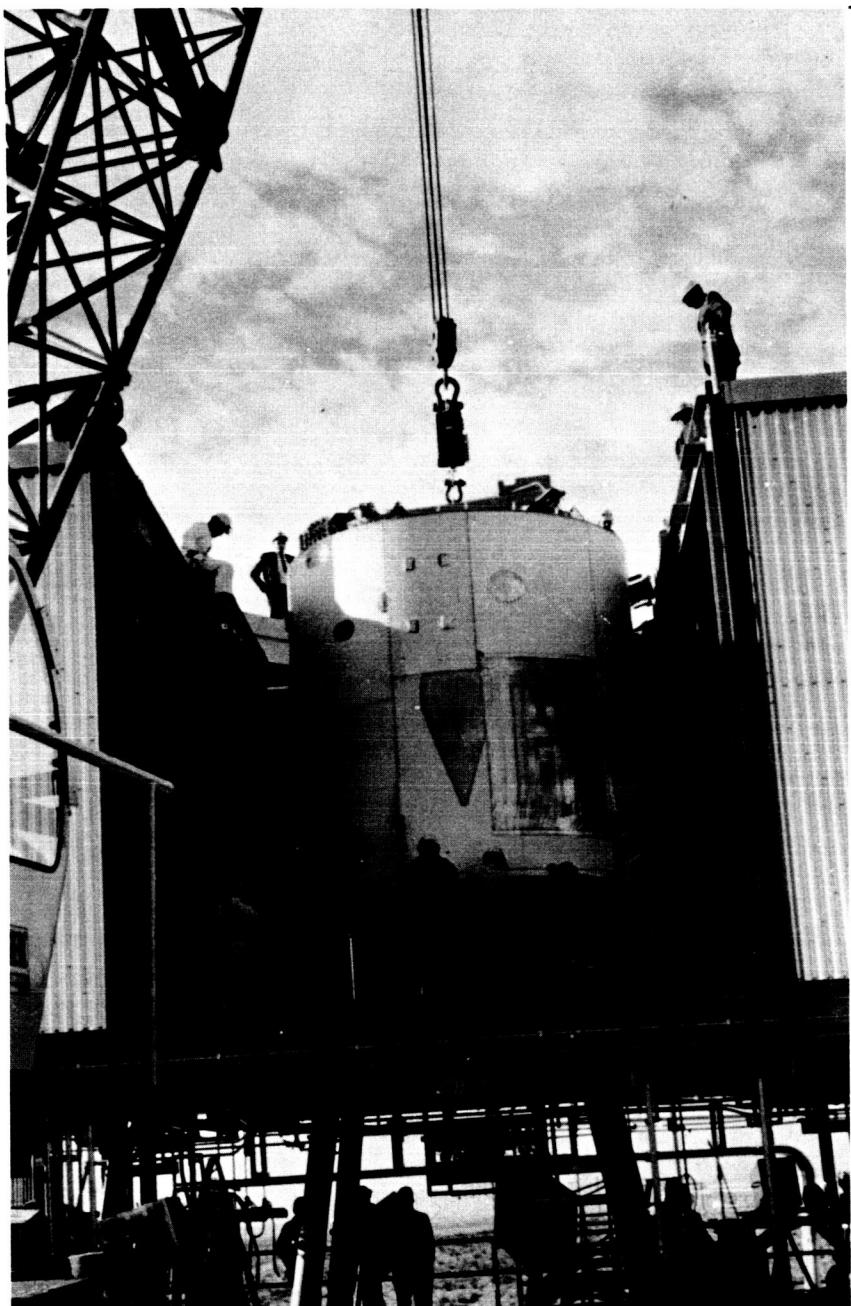


Figure I-13. Service Module Airframe 001 in propulsion engine test stand.

Airframe 004 was used for structural static tests to determine its behavior under various loads that could be experienced during flight, such as boost and service propulsion system engine firing. The combined Command and Service Module was subjected to simulated loads that will result during the Saturn V boost phase.

CSM-007, another Block I spacecraft, was also in test during the period. Acoustics tests of its Command Module at the contractor's plant were completed in September, and in November flotation and water impact tests were initiated at the contractor's facility. These will be followed by flotation tests at the Manned Spacecraft Center beginning in 1966. Subsequently, Command Module 007 will be used for Block II postlanding tests. Manufacture of the lunar-configured Block II spacecraft began in August, an important milestone for the period.

*Lunar Module.*—Another spacecraft milestone was the beginning of fabrication of four additional Lunar Module (formally Lunar Excursion Module) test versions for delivery in 1966. Also, the last of three previously manufactured Lunar Module test versions was being prepared for equipment installation. (Fig. 1-14.)

Testing of the Lunar Module spacecraft began shifting from components to subsystems. Component and subsystem-level testing was conducted by the subcontractors. Higher level rig and Lunar Module test version testing was conducted at the prime contractor facilities, Arnold Engineering Development Center, White Sands Test Facility, Marshall Space Flight Center, and at the Tulsa Facility of another contractor.

Lunar Module ascent-stage proof pressure tests were successfully completed in September 1965 on the Lunar Module full-scale thermal model. The ascent stage of this model will be refurbished for use as the ascent stage of Lunar Module Test Article 5 in Lunar Module propulsion system tests at White Sands Test Facility.

At the Arnold Center in Tullahoma, Tenn., heavyweight ascent and descent engine rig firing tests were conducted to determine the Lunar Module engine performance characteristics in flight.

Heavyweight and prototype-weight ascent and descent engine tests were conducted at the White Sands Test Facility. The prototype tests consisted of nonfiring (cold flow) tests of the descent engine fuel system. These are conducted prior to engine firing tests to make sure that the fuel system functions properly.

At contractor facilities in Tulsa, Lunar Module Test Article 10 (LTA-10) was subjected to static structural tests in combination with the spacecraft adapter. In August, the adapter for the first Apollo-Saturn flight early in 1966 was delivered to Kennedy Space Center.



Figure 1-14. A mockup of the Lunar Module.

The adapter is the external space vehicle structure which houses and supports the Lunar Module between the spacecraft Command/Service Module and the instrument unit of the launch vehicle. LTA-10 later will be refurbished to become the Lunar Module of the spacecraft payload for the first Saturn V flight test in 1967.

At Marshall Space Flight Center, LTA-2 was mated with the Saturn launch vehicle to undergo dynamic structural tests. Such tests verify the launch vehicle-payload structural integrity under the simulated launch and flight dynamic load conditions for both earth-orbit missions and the lunar mission. Preparations began during the period for the higher level integrated Lunar Module systems tests which will get underway in 1966.

*Guidance and Navigation Systems.*—All development and essential ground qualification testing of Block I Command Module guidance

and navigation systems was completed during the period. Ground qualification will be completed early in 1966. Twelve of fifteen production Block I systems, to be used for flight testing and earth-orbital flights, were assembled, tested, and delivered for spacecraft installation. (Fig. 1-15.)

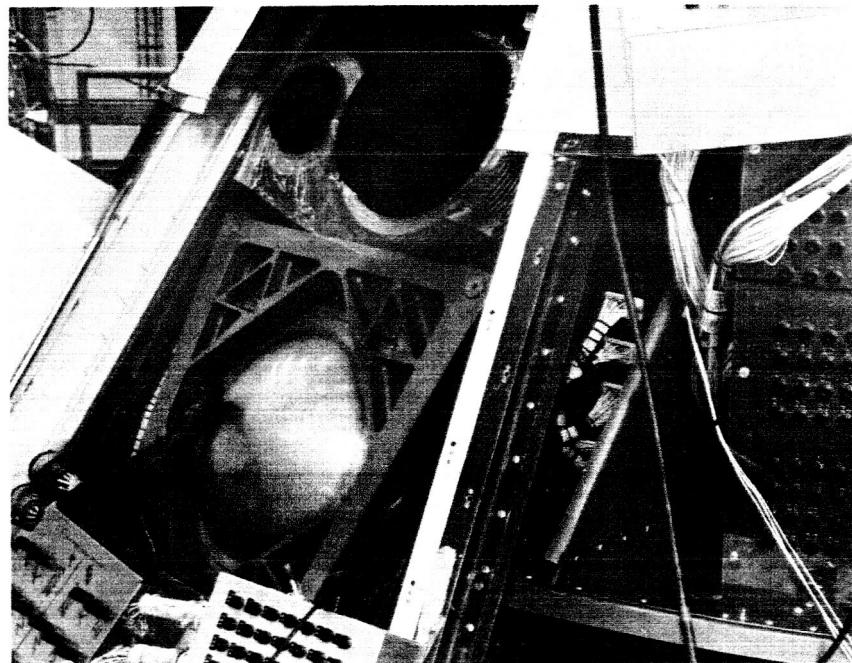


Figure 1-15. A Block I Command Module guidance and navigation system.

Design and development of the lighter Block II system, which will be used on both Command and Lunar Modules for lunar flights, also were completed during the period. Engineering models of this system underwent extensive ground testing.

*Launch Escape System.*—Qualification of the Apollo spacecraft launch escape system neared completion during the period. The final test using the Little Joe II, originally scheduled for December, was postponed until January 1966 when a malfunction was detected in the test vehicle guidance system.

*Logistics.*—The logistics base for the Apollo program was built up during the period. Barges for transportation of hardware on the West Coast, and from the West Coast to the East Coast, were placed in operation. The second stages of both the uprated Saturn I and the larger Saturn V were transported by barge during the period. The

first of the big Saturn V first stages also was barged from Michoud Test Facility, La., to Marshall Space Flight Center.

Work continued on the five ships and the various aircraft associated with the Apollo operations network in preparation for future Apollo-Saturn space vehicle flights.

#### Launch Vehicles

The last of the Saturn I vehicles was launched on July 30, 1965, carrying a Pegasus satellite into orbit. With this success, a perfect 10 out of 10 launches was achieved.

The Saturn I program was the steppingstone to Apollo manned flights with the uprated Saturn I and the Saturn V. Its accomplishments included the development of new fabrication techniques, new transportation methods for large rockets, and successful clustering of several large rocket engines. Saturn I also provided the first extensive use of multiengines and liquid hydrogen in the upper stages. In addition, the program advanced the technology of guidance, of instrumentation and of handling and storing large quantities of cryogenic fuel. Finally, Saturn I proved the validity of NASA's ground test philosophy, verified the aerodynamics of Apollo spacecraft, and served as the launch vehicle for three meteoroid satellites (two in the previous report period).

*Upgraded Saturn I.*—During the report period, tests were nearly completed in the major ground testing activity required to launch the first uprated Saturn I launch vehicle.

The first stage (S-IB) test program carried out during the period included structural tests, component qualification tests, and intensive checkout tests of the flight stages. During the structural tests, all stage components were subjected to loads exceeding design limits. These tests were conducted both at the Marshall Space Flight Center (MSFC) and at Michoud.

The intensive component qualification testing program initiated previously was continued during the period. More than 10,000 of these tests were conducted at MSFC, and at both contractor and subcontractor plants. During these tests the components were subjected to environmental conditions which are expected to be experienced under actual flight.

In addition to the development tests conducted for the first stage, the first flight version of it completed its checkout tests during the period.

The first stage of the uprated Saturn I is a direct derivative of the Saturn I first stage with uprated H-1 engines. Both of the AS-201 (Apollo-Saturn-201) flight stages were static fired and delivered to

KSC as planned during the period. The first stages of both AS-202 and AS-203 and the second stage (S-IVB) of AS-202 also were static fired. (Fig. 1-16.)

Tests of the uprated Saturn I second stage (S-IVB) during the period included structural, component qualification, and checkout tests of the flight stage for the first flight. Structural tests were successfully conducted on all major stage assemblies at Seal Beach and were subjected to loads exceeding design limits.

In September 1965 the first stage of the Apollo uprated Saturn I-AS-201 space vehicle (S-IB-1) was delivered to KSC. Following routine manufacturing, static firing, and poststatic checkout, this stage was mated with the facilities checkout stages and spacecraft modules on Launch Complex 34 for integrated launch facility/space vehicle checkout. The use of the S-IB-1 flight stage for these tests allowed the continued use of the S-IB-1 dynamic/facility stage for dynamic testing at MSFC.

During a prelaunch test operation, inadvertent damage to one of the S-IB stage fuel tanks resulted in the replacement of the damaged tank while the stage remained on the pad. This replacement took place in about 24 hours without impact on the prelaunch test schedule.

On August 8, 1965, the AS-201 second stage (S-IVB) was successfully acceptance-fired at the Sacramento Test Facility. The stage arrived at KSC on September 3, 1965, following postfiring checkout and shipment via oceangoing freighter through the Panama Canal.

The instrument unit ground tests also were completed during the period. Assembly of the instrument unit to be flown on the first flight vehicle was completed in August and it was then delivered to Cape Kennedy.

*Saturn V*.—Consistent with the Apollo test philosophy, extensive Saturn V vehicle ground tests were accomplished during the report period. Testing was performed on flight-type stages down through the components level to insure that the Saturn V hardware will meet operating requirements encountered during the manned lunar mission. (Fig. 1-17.)

The all-systems first stage (S-IC) test program for the Saturn V launch vehicle was completed at Marshall Space Flight Center in November, 2 months earlier than planned. The early completion was made possible by timely hardware delivery and a highly successful firing program.

Captive firing of the all-systems first stage was initiated in the previous period to verify the overall propulsion system performance and establish system limits.

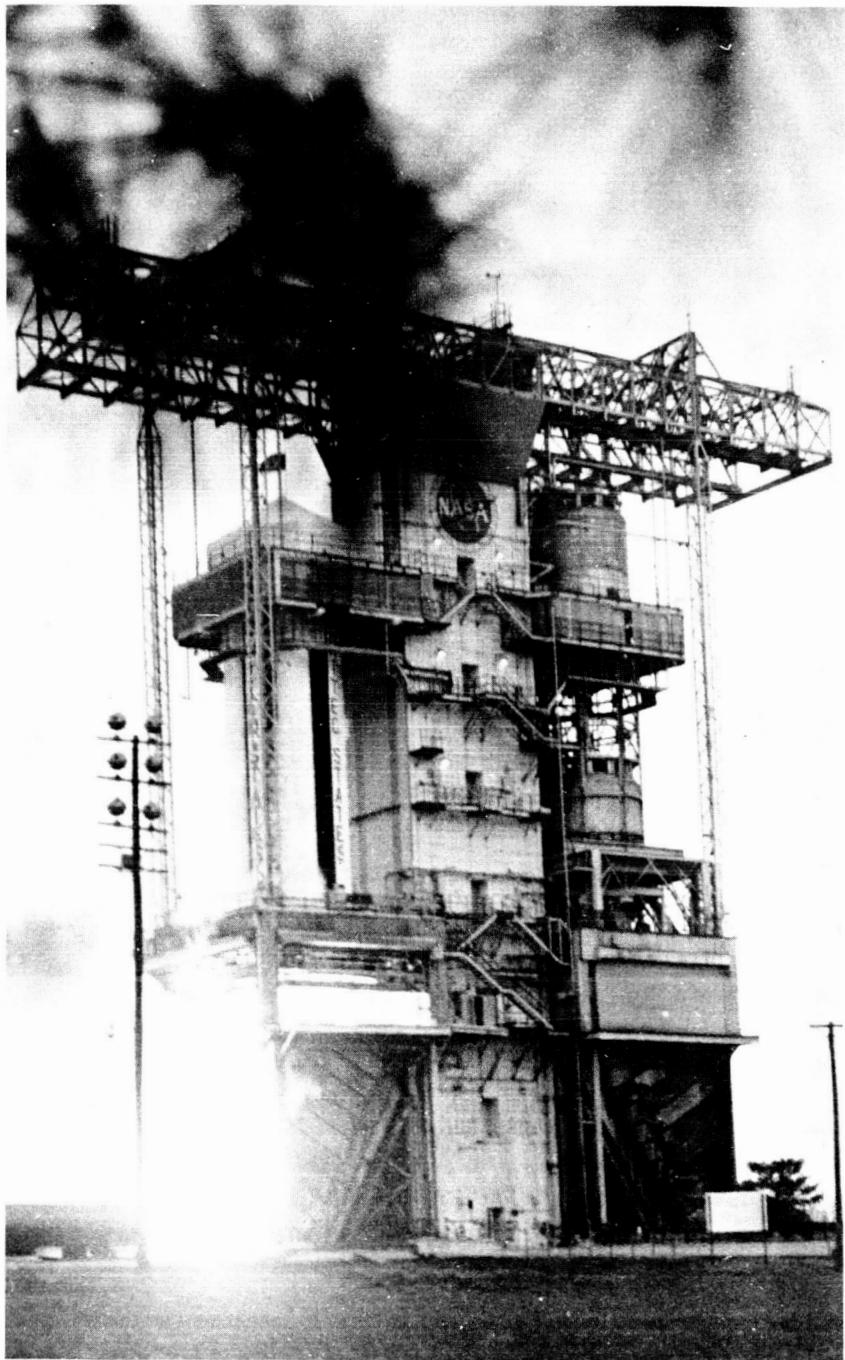


Figure 1-16. Test firing first stage of the uprated Saturn I.

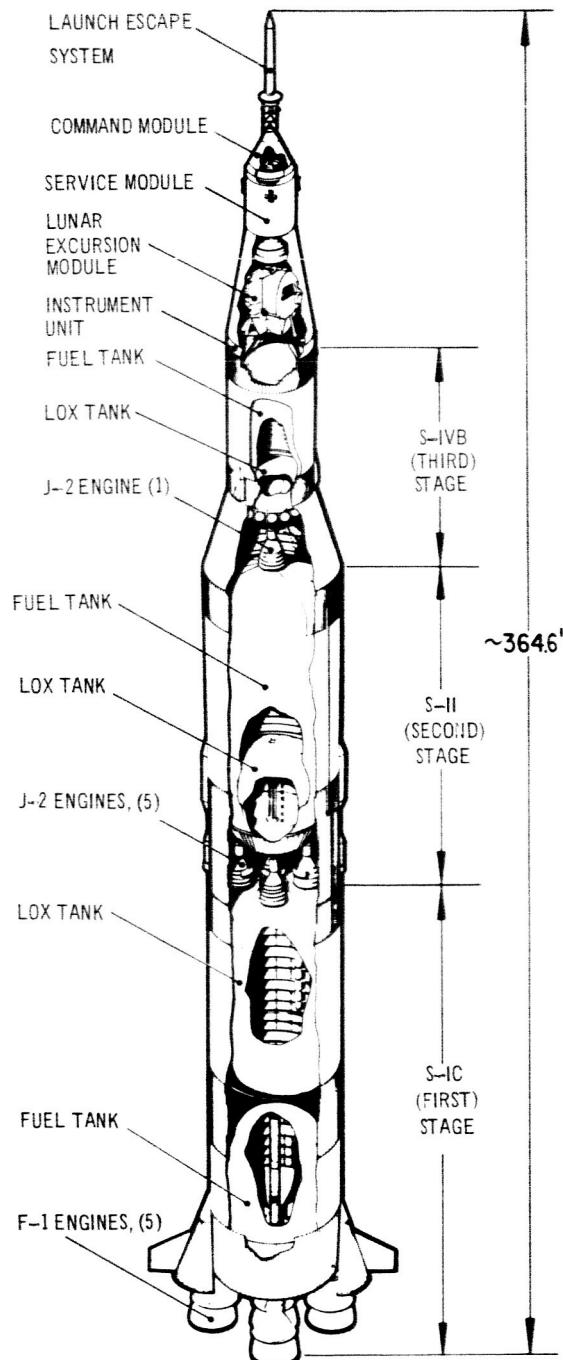


Figure 1-17. Line drawing of Saturn V.

A single-engine firing of the first stage was subsequently expanded to a full cluster of five engines; manual firings were converted to automatic; and firings of but a few seconds duration were progressively increased to full duration of 150 seconds.

Five flight and 4 ground test first stages out of 19 to be delivered were in various phases of manufacture and assembly at the end of 1965. The first flight stage was delivered from manufacturing to checkout at MSFC. (The first two flight stages were being manufactured at MSFC and subsequent stages manufactured at Michoud.)

Delivery of the dynamic test stage was made to MSFC by Michoud to support the Saturn V dynamic test program, scheduled to start early in 1966. This was the first Michoud-built stage. The second, a facility checkout stage to be used for checking out the Saturn V launch complex, was also completed and will be delivered to KSC early in 1966.

Structural integrity testing on the flight-type second stage (S-II) and instrument unit was completed. Structural tests on the Saturn V first and third stages should be completed early in 1966. Components were tested to verify their designed load carrying capability and margin of safety.

The electromechanical mockup, common bulkhead test tank, and structural test programs were all completed for the second stage. The common bulkhead, which is probably the most critical component in the second stage, was structurally certified when subjected to critical design loads and temperature.

In September, during testing of the structural test stage at the contractor's facility at Seal Beach, Calif., the unit was destroyed. This occurred while the stage was being subjected to a planned loading to 140 percent of its design limit. It failed at 138 percent of this limit, demonstrating that an optimum second-stage structure had been designed.

The F-1 engine for the Saturn V first stage completed the first single-engine firing and the first cluster-engine firing on the all-systems test stage (S-IC-T) in the previous period, approximately 3 months ahead of schedule. More than 46,000 seconds of systems R&D testing were carried out by the end of December (approximately 55 percent of the total system tests conducted to date).

A cluster of five J-2 engines provide the propulsion for the second stage. A single J-2 engine is used with the third stage (S-IVB). Its flight rating test program was completed in July 1965. During this test program, the J-2 engine was subjected to 25 tests for 2,750 seconds of accumulated firing time, demonstrating the necessary reliability for the flight program in the uprated Saturn I. (Fig. 1-18.)

Qualification testing of the 200,000-pound-thrust J-2 engine was completed in December, with an accumulated ground test firing of about 90,000 seconds in 1,400 tests. During the formal qualification test program, a single engine was subjected to 30 tests with an accumulation of 3,750 seconds in firing time. A reliable restart capability was demonstrated in these tests; such reliability is a necessary requirement for early manned flights on the Saturn V.

Five-engine cluster firings for the second stage of the Saturn V (S-II) and single-engine firings for the third stage of the Saturn V (S-IVB) also were conducted. Forty-two production engines were delivered in support of the ground and flight test programs.

#### Apollo Support

Ground support equipment was installed and checked out at Kennedy Space Center to make the facilities ready for checkout of the Command and Service Module (CSM-009) for the first Apollo-Saturn flight. The CSM-009 was received at KSC in October for inspection and testing. All facilities for the CSM-009 checkout were operationally ready at that time to provide the necessary support.

Among these facilities brought into use during the period was the Propulsion Test Facility, the former Titan Launch Pad 16 at Cape Kennedy. This facility was converted to perform functional checks and to static fire the Service Module Secondary Propulsion System in support of the CSM-009 checkout.

Another was the Hypergolic Test Facility No. 1, activated to test the Service Module reaction control system thrusters and the Command Module reaction control system. Each individual thruster fuel, oxidizer, electrical, and instrumentation system was verified at this facility. Also, the complete Command Module was taken to it for checkout of the reaction control system.

Also activated during the period was the Pyrotechnic Installation Facility. Here, the Command Module earth landing system, the recovery system, and the forward heat shield with associated pyrotechnic devices are installed. The Launch Escape System checkout and weight-and-balance functions also are performed here.

The first integrated system checkout of the Apollo spacecraft was begun on CSM-009. The Command Module was mated with the Service Module in the integrated system test stand where the interface, combined systems, and polarity tests were performed. The Command and Service Modules were then mated with the spacecraft adapter for transport to the launch complex.

Two spacecraft checkout systems, installed during the previous report period in the Operations and Checkout Building at Cape

Kennedy, became operational during the period. These provide centralized control and real-time monitoring of operations during spacecraft checkout and launch countdown. Each consists of a control room and computer room. A signal distribution system allows either control room to be connected to either computer room and the computer rooms may be connected to any test facility. The checkout stations thus are able to control and monitor spacecraft checkout at Launch Complex 34. Additional control consoles are located in the Launch Control Center for the launch controllers. Data to these consoles are supplied by the checkout stations.

Ground support equipment installed on Launch Complex 34 was activated to support the CSM-009 prelaunch checkout and launch. This equipment provides the capability for spacecraft-to-launch-vehicle interface tests, spacecraft systems tests, countdown demonstration, and fuel servicing.

### Apollo Applications

Apollo Applications is a product of the study and planning effort that has evolved during the past 3 years. It has come about as a result of several funded studies and related in-house analyses which have been performed since the lunar orbit rendezvous was selected as the mode for accomplishing the manned lunar landing mission.

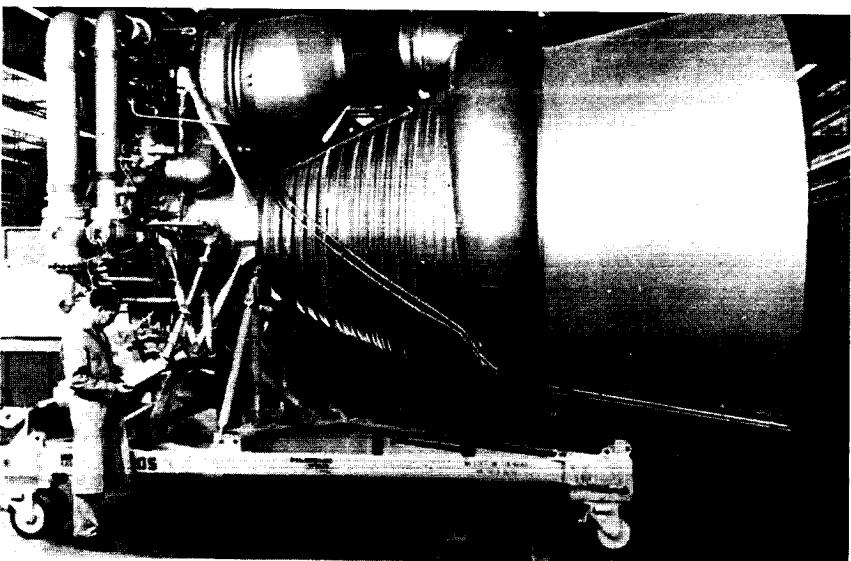
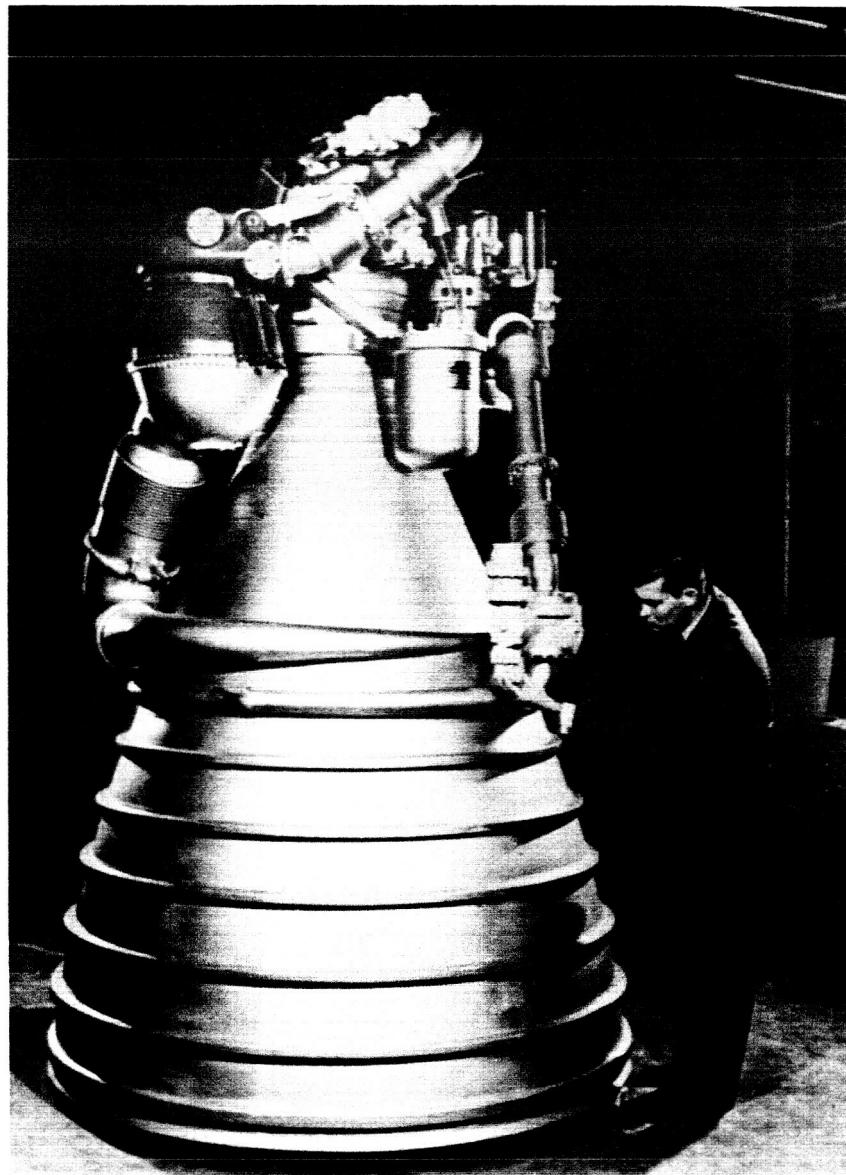


Figure I-18. The F-1 (above) and J-2 engines (facing page).

A major factor in the selection of the lunar orbit rendezvous for the Apollo mission was that the Saturn-Apollo systems required for this mode would provide a powerful and flexible manned space exploration capability as a product of the Apollo program. Progressing concurrently with the definition and development of the Apollo program, the



advanced system studies have identified a variety of mission objectives which could be accomplished with varying degrees of adaptation and modification of the basic lunar mission hardware. Apollo applications has resulted from the narrowing down of the many possible adaptations to a limited number of specific missions.

As the current Gemini and Apollo programs are building on results from earlier successful manned space flight programs, so these programs should provide a new level of capability upon which to base Apollo Applications. As a result, NASA expects to be able to explore space out to 250,000 miles from earth and to conduct manned operations and experiments on flights up to 2 weeks' duration. The uprated Saturn I and Saturn V boosters should be able to inject approximately 18 and 140 tons of payload, respectively, into near-earth orbit. The Saturn V should be capable of sending 48 tons to the vicinity of the moon. Further, the Apollo spacecraft should have the capability to sustain a three-man crew in a two-compartment, highly maneuverable, modular vehicle, able to land two men on the moon and return them, with samples of lunar material, to earth.

The basic Apollo mission will develop the capability for three men to operate in earth orbit for up to 14 days or in lunar orbit for 4 to 8 days if no landing is involved. It should also be able to place two men on the lunar surface for 24 to 36 hours.

Added capabilities include those of placing two or three men in earth orbit for 6 weeks on a single launch mission and up to 3 months through rendezvous resupply; placing three men in lunar orbit for periods up to 28 days; and sustaining two men on the lunar surface for periods of up to 2 weeks. Studies in the past 3 years indicate that the added capabilities are inherent in the system without major modifications.

The major operational objectives of Apollo Applications would be (1) manned synchronous and high inclination orbit operations; (2) orbital assembly and resupply operations including personnel transfer; (3) land landings; (4) long-duration manned space flight operations; and (5) extended lunar exploration operations.

Planning schedules for Apollo Applications have been prepared for the time period 1965 through 1971. These schedules are based on the technology being developed in the Apollo-Saturn I and Apollo-Saturn V programs, and on the resultant capabilities.

The Apollo program schedules call for the first unmanned flight in 1966 on the uprated Saturn I; the first manned Apollo flight on the uprated Saturn I in 1967; and on the Saturn V, the first unmanned and manned flights in 1967 and 1968. Thus, beginning in 1968, the possibility of alternate missions to those in the mainstream Apollo

program can be considered, using the nominal spacecraft for 14-day missions in earth orbit and 8-day missions in lunar orbit.

It appears that the technology would permit 4-week missions in earth orbit with a single launch in about 1969 and up to 3 months by double rendezvous in 1971. This same spacecraft should be capable of 28-day missions in lunar orbit during 1970-71. Similarly, using the inherent capabilities in the basic Lunar Module, NASA believes a 2-week lunar surface exploration capability is possible a year or two after the initial manned landing.

The Apollo Applications Office was established in July 1965, and the headquarters organization was approved in August. The roles and missions of the centers were determined in December.

The Manned Spacecraft Center, Houston, has the responsibility of developing Apollo Applications extended-capability spacecraft subsystems. In addition, MSC will also be responsible for integrating experiment payloads on the command and service modules.

The Marshall Space Flight Center, Huntsville, Ala., in addition to its responsibility for launch vehicle procurement, will be responsible for integrating payloads on the Lunar Module, the Saturn interstage, and the instrument unit.

The Kennedy Space Center, Fla., will be responsible for Apollo Applications launch operations and will also be responsible for the installation of experiment equipment in the alternate mission phase. Additionally, the Kennedy Space Center will have the capability of installing late-delivered experiment equipment during the follow-on mission phase.

Preliminary flight mission assignments for Apollo Applications were completed in December, and a preliminary program development plan was issued. NASA completed a phase B definition of the extended duration spacecraft and payload integration activity. The Agency also identified 314 possible experiments, completed the phase B studies of the Manned Space Flight Network/NASA Communications (NAS-COM) capabilities to support Apollo Applications missions, and completed studies of launch operations and mission operations support.

### **Advanced Manned Missions**

In examining possible recommendations for the next major manned program, NASA continued to study three program areas during the period. These program areas cover the major candidate approaches which might be considered within the context of the NASA charter. These areas are earth-orbital, lunar, and planetary.

The earth-orbital area continued to receive major study effort. The fundamental categories in this area are those related to mission identi-

fication and experiment support, those directed toward specific space station configurations, and those directed at definition of the ferry and logistic systems which would resupply earth-orbital space stations.

The lunar studies that were in progress can be divided into four basic categories: those to derive mission requirements, those associated with lunar exploration systems, those related to transportation systems, and those concerned with evaluating the supporting operations.

The third area of advanced manned mission studies is concerned with possible manned missions to planets of our solar system. The current planetary mission studies break down into the areas of mission requirements, systems studies, and operations and support. Mission requirements studies are focused on two general types of missions. These types are capture missions, in which the spacecraft could orbit the target planet and perhaps send a landing vehicle down to the surface; and fly-by missions, in which a landing is not attempted.

Studies also have been conducted to define requirements for flight vehicles to support missions in the above three program areas.

## Facilities

Significant accomplishments were made in the construction of facilities for the development fabrication, test, checkout, and launch of manned space vehicles. At the Kennedy Space Center, Fla., where space vehicles are checked out and launched, progress continued to assure that the facilities will be ready for the Apollo-Saturn V launches. At the Manned Spacecraft Center, Houston, most major facilities have been completed. Spacecraft development testing and astronaut training were conducted consistent with program schedules. The Lunar Module Test Facilities at the White Sands Test Facility, N. Mex., were completed and became operational. At the Marshall Space Flight Center, Ala., and the Michoud Assembly Facility, La., facilities for development, manufacture, and test of spacecraft and launch vehicle hardware were in a fully operational status. The Mississippi Test Facility (MTF) is an outstanding example of the advances made during the last half of 1965. During 1966, MTF, which will be the site of acceptance testing of the first two stages of the Saturn V launch vehicle, is scheduled to move from the construction and activation phase to the operational phase.

### Kennedy Space Center

Two key facilities became operational at the Kennedy Space Center: Launch Complex 34, modified for uprated Saturn I launches, shown in figure 1-19; and the Apollo Static Test Facility for prelaunch

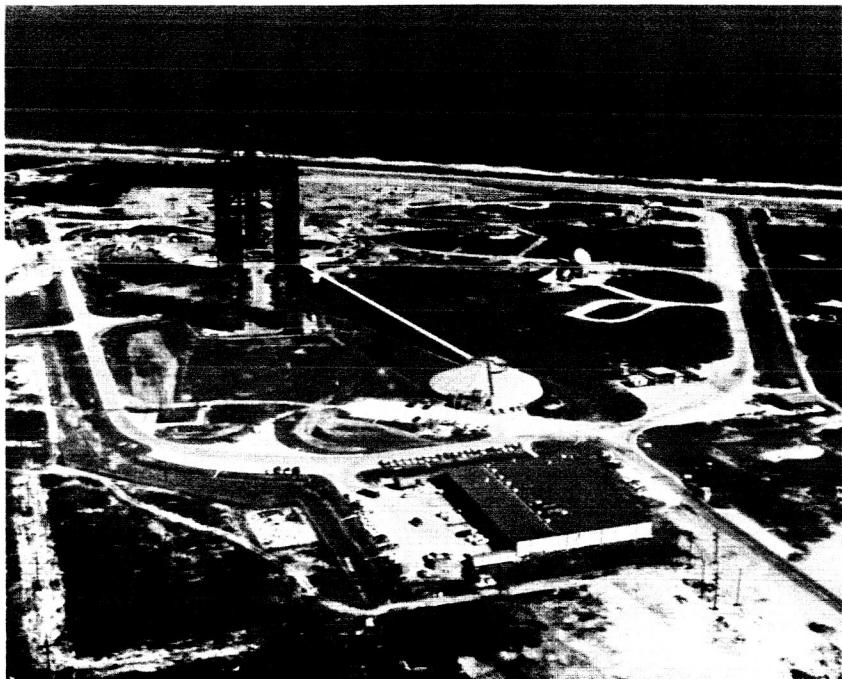


Figure 1-19. Launch Complex 34.

static tests of the propulsion module engine. In addition, the following supporting facilities became operational: central instrumentation facility for the uprated Saturn I; range instrumentation sites; ordnance storage facility for Launch Complex 39; vehicle maintenance and service facility; and the launch equipment shop. Construction was also completed on cryogenic building No. 2; hypergolic building No. 2; flight-crew training building; Pad A and crawlerway of Launch Complex 39; instrumentation building for Launch Complex 39; and the low bay and high bay No. 1 of the vehicle assembly building at Launch Complex 39. Contracts were awarded for construction of the following facilities: modifications to Launch Complex 37B required for the uprated Saturn I; Launch Complex 39 items such as intercommunication systems, instrumentation, and communications cabling; and crawlerway surfacing and widening.

#### Manned Spacecraft Center

At the Manned Spacecraft Center, Tex., most major construction has been completed. During the last half of 1965, the anechoic (free

from echoes) test chamber building and antenna test range, the vibration and acoustic test laboratory, and the contractor support facility became operational. Construction is continuing on the flight acceleration facility and the environmental simulation laboratory.

### **Marshall Space Flight Center**

At the Marshall Space Flight Center, Huntsville, Ala., the following facilities became operational during the last half of 1965: the F-1 engine static test stand; the components test facility; the acoustic model test facility; and the hangar for vehicle components and assembly station. In addition, contracts were awarded for the construction of a nondestructive testing laboratory; an extension to the test engineering building; and an addition to the materials laboratory.

### **Michoud Assembly Facility**

The Michoud Assembly Facility, a Government-owned, contractor-operated plant located outside New Orleans, La., is the site for manufacture and assembly of uprated Saturn I and Saturn V booster stages. Major construction is complete and the plant is operational. Since July of 1965, the road system for transferring Saturn first stages from the plant to the barge dock has been operational. Soon to be completed are the vehicle component supply building, the contractor service building, extension to the marine dock, and improvements to the storm drainage system.

The Michoud Assembly Facility sustained considerable damage during Hurricane Betsy in September 1965. However, repairs were completed in December, and the facility continued to operate without a break in program schedules.

### **Mississippi Test Facility**

This facility, located on the banks of the East Pearl River in southwestern Mississippi, will begin operational testing of Saturn V second stages in 1966. The Saturn V first stages are scheduled for testing at this location by the end of 1966.

During the period, the following major technical and supporting facilities were completed and readied for operational use: the Saturn second-stage static test stand and control center, the data acquisition facility, the central control facility, the high-pressure water facility, the cryogenic transfer station, the acoustical building, the meteorological building, the test maintenance building, the laboratory and engineering building, the flammable materials and compressed gases storage facility, and the electronic instrumentation and materials laboratory.

### Various Locations

*Seal Beach.*—The Saturn V second stage is manufactured at a Government-owned, contract-operated plant located at Seal Beach, Calif. Construction efforts at Seal Beach during the period were concentrated on the completion of the vertical checkout facility. (Fig. 1-20.) The plant is fully operational.

*Sacramento Test Operations.*—The Sacramento Test Site, operated for the Government by a contractor, is devoted to the static testing of Saturn V third stages. The checkout test facility, used for poststatic and center-of-gravity determinations, was completed during this period.

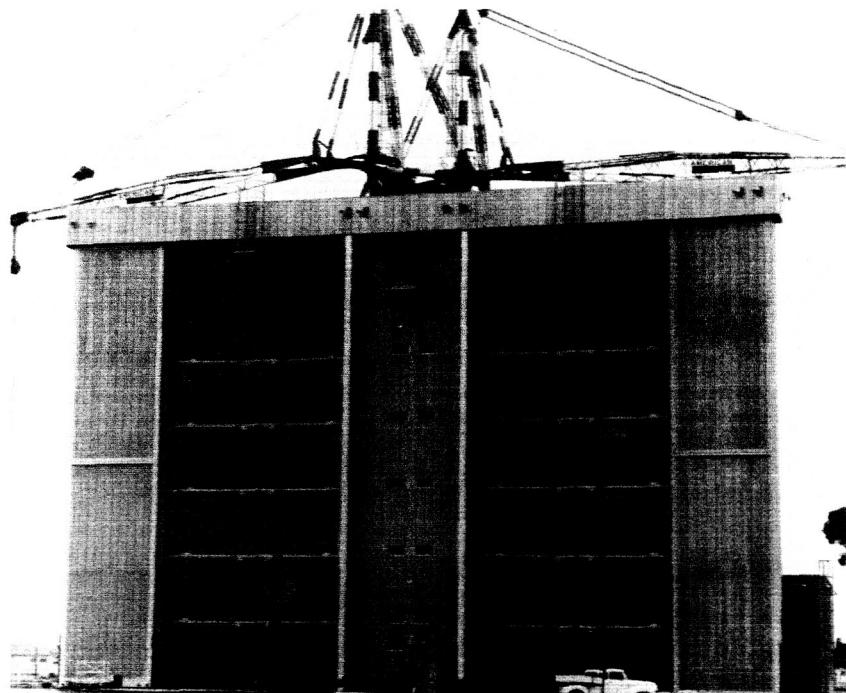


Figure 1-20. Saturn V second (S-II) stage vertical checkout facility, Seal Beach, Calif.

*White Sands Test Facility.*—This facility, located near Las Cruces, N. Mex., became fully operational during the last half of 1965. The Lunar Module test facilities which test the module's ascent and descent engines were completed. These facilities, in addition to the currently operating propulsion module test facilities, provide this test site with a sound capability for developmental testing of all spacecraft propulsion elements.

## Space Medicine

The space medicine activities were primarily concerned with the manned Gemini flights that occurred during the period. Other efforts were directed toward coordination with the USAF bioastronautics program, toward the development and publication of space medicine reports, and toward the medical data analysis program.

### Gemini Medical Experiments

The medical experiments program is concerned with crew safety and welfare in future flights—emphasizing detailed measurement in the gathering of trend information to predict and prevent undesirable effects during planned manned flight missions of the future. It should be emphasized that it is realistic to consider a medical experiment on a single flight as a run of the experiment rather than as a complete experiment. Repetition of experiments is scheduled for statistical validity as well as for additional information.

The Gemini experiments consist of the cardiovascular conditioning (M-1), exercise (M-3), phonoelectrocardiogram (M-4), bioassays of body fluids (M-5), bone demineralization (M-6), calcium balance (M-7), in-flight sleep analysis (M-8), and otolith (a part of the body balance system located in the inner ear) (M-9) studies. Gemini V carried five medical experiments—M-1, M-3, M-4, M-6, and M-9; Gemini VI-A carried none; and all Gemini medical experiments were carried on Gemini VII.

The cardiovascular conditioning experiment, commonly referred to as the cuff experiment, is the evaluation of a technique to prevent cardiovascular deterioration as observed by the tilt table and other procedures. Thus far, its significance is uncertain. On Gemini V, there appeared to be some indication that the cuffs were a protective factor. (Fig. 1-21.) This apparent trend, however, was not evident on Gemini VII. Whether the results of this experiment on the two missions simply represent individual variations or whether the cuff procedure can be an effective deterrent to cardiovascular deterioration remains to be determined.

The exercise experiment, performed with a bungee cord, is an evoked response experiment designed to measure cardiovascular responses to the same fixed stimulus as the flight continues. The results showed no significant changes from preflight norms in the astronauts in either Gemini V or Gemini VII.

The phonoelectrocardiogram simultaneously records the electrical activity of the heart and the sound made by closure of valves at a particular point in the contraction of the heart, thus providing a means to

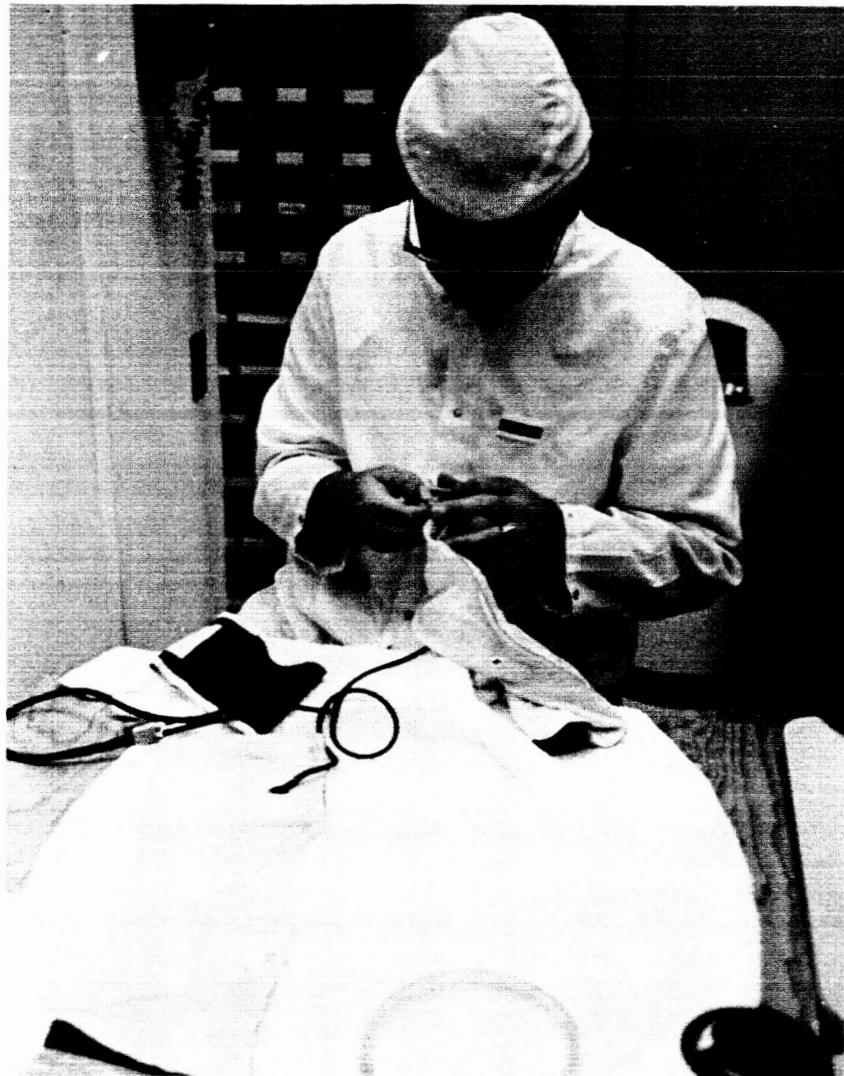


Figure 1-21. Technician checking cuffs used in cardiovascular conditioning experiment.

measure the time interval between stimulus and fixed point of response. An increase in this time interval can be interpreted to indicate a decrease in heart muscle responsiveness or a deconditioning of the heart muscle. Results so far are very preliminary. Computer analysis of data from Geminis IV, V, and VII flights was in progress at the end of the period. Preliminary viewing of the data showed no significant change between ground and flight measurements. All that could be

concluded at year's end was that there seems to be no evidence of myocardial deconditioning in space flight.

The bioassays of body fluids experiment is designed to study the astronauts' reaction to stress by means of analyzing body fluids. Blood and urine samples are taken preflight and postflight, and urine samples in flight. Analysis will indicate stress effects on hormones, electrolytes, proteins, amino acids, and enzymes. Analysis for Gemini VII, the first flight on which this experiment was scheduled, was underway.

The bone demineralization experiment employs standard X-ray equipment to determine the density of heel and fifth-finger bones before and after flight. In both Gemini IV and Gemini V, a diminution of bone density, roughly comparable to changes seen after 2 weeks of bedrest, was noted in the bones of all four astronauts. These changes did not have any observable effect on astronaut tolerance or efficiency.

The objective of the calcium balance experiment is to evaluate the rate and amount of calcium change during conditions of orbital flight. The experiment also monitors other electrolytes of interest such as nitrogen phosphorus, sodium chloride, and magnesium. First flown on Gemini VII, the analysis of data was not completed at year's end. This is also true of the in-flight sleep analysis experiment, designed to assess the astronauts' state of alertness, levels of consciousness, and depth of sleep during flight.

The human otolith function experiment seeks to evaluate the function of the otolith mechanism by two methods: the preflight and post-flight measurement of ocular counterrolling and by in-flight evaluation of egocentric visual location of the horizontal. Data derived so far from Gemini V tend to indicate that ocular counterrolling was unchanged postflight as compared to preflight. In the other parameter observed, data were inconclusive.

In summary, the Gemini medical findings to date indicate that there have been no overt manifestations of vestibular disturbances, no hallucinations, and no indication of conditions that would be expected to cause hallucinations. Sleep and diurnal rhythm changes tended to normalize spontaneously, and there were no operationally limiting manifestations of circulatory impairment or symptoms of musculoskeletal disturbance.

In terms of trend information, as distinct from symptoms, the cardiovascular deconditioning trend occurred as expected but no disability was observed in 14 days. No evidence of myocardial (middle muscular layer of heart wall) change has been demonstrated so far. A dehydration trend continued; but one of the most likely causes, a

less than optimally efficient environmental control system, seems to be ruled out.

As far as the musculoskeletal system is concerned, an early disuse atrophy was demonstrated, but this is entirely consistent with the reduced muscular activity of flight.

There has been no evidence of behavioral, metabolic, or respiratory change to date, although specific measurements must await later flights.

The Gemini program has thus far demonstrated that man can function well in space for the duration of the planned Apollo lunar landing and earth orbital missions without in-flight or postflight disability or degradation of practical consequence. The experience of Gemini VII, together with the medical trend information obtained, significantly increases medical confidence in the feasibility of manned missions for 30 days or more.

#### Program Coordination

The NASA space medicine and USAF bioastronautics programs coordination for fiscal year 1966 was concluded during this period. The coordinating activity covered 781 Air Force and 212 NASA tasks. In this year, the close task-level, scientist-to-scientist relationship developed since 1963, when the coordinating procedures were first instituted, demonstrated its effectiveness in that no tasks could be identified for cancellation because of unwarranted duplication of effort.

#### Publications

Through contractual or in-house effort, two numbered NASA reports were published and three others were in the process of publication. Two other contractual reports were in review prior to submission as NASA numbered reports. Five other reports, not immediately designated for inclusion in the NASA numbered report series, were also prepared through the auspices of the space medicine program. Studies were initiated to produce an additional five reports during the next 18 months.

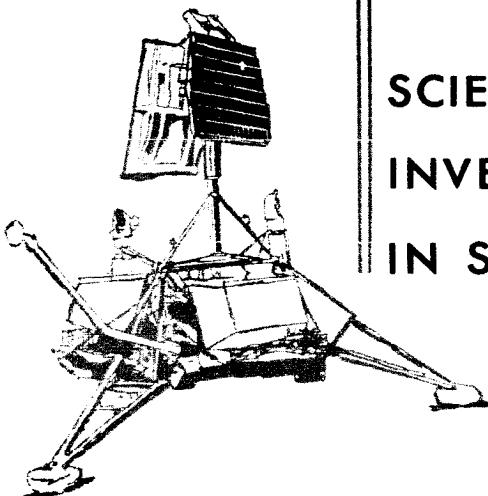
#### Medical Data Analysis Program

In the area of medical data analysis and reduction, an ongoing activity of the space medicine program, a pilot demonstration of the use of computers in the measurement, analysis, and interpretation of in-flight electrocardiograms was successfully attempted with Gemini VII. This effort demonstrated the feasibility of a method which can relieve the medical monitor of the necessity for visually inspecting and estimating waveform trace measurements covering literally miles of recording paper. Electrocardiograms obtained during Gemini III

were also arranged for visual inspection by a contourographic display system. This system is represented by the analog waveform of each single heart cycle recorded one below the other from the face of an oscilloscope on a moving film. Since the oscilloscope light beam intensity is proportional to the waveform amplitude, the resulting contourogram appears to have a third dimension much like a relief or contour map. This format proved to be highly desirable in long-term monitoring situations. One reason is that where waveform is the consideration, the analog of a 6-hour electrocardiogram in common practice would be written along 1,800 feet of strip chart recording paper. The contourographic technique reduces this to 6 feet. The compacted format also allows the scanner to note small changes in rate and slight differences in waveform while maintaining the details in proper time perspective over the course of long periods of time.

The medical data analysis program included other activities during the period. Mathematical models of in-flight medical experiments in Gemini missions were being worked out to allow for subsequent computer analysis of the data. Astronaut preflight, in-flight, and post-flight clinical laboratory data collected during the Mercury program were being filed on magnetic tape for immediate retrieval, analysis, and comparison. The system will provide the flexibility necessary to accommodate data from the Gemini, Apollo, and follow-on programs.

The automatic reduction and analysis of astronaut voice data was in progress, although at the present time it is premature to estimate the feasibility of this technique. Work was progressing on the task to provide NASA with the capability of committing medical records to storage for instantaneous retrieval in any of several ways, such as tabular form or graph, in hard copy, or on cathode-ray tube display. This system will permit the physician, physiologist, or other medical specialist to directly study the medical records without intermediate actions by the computer technicians.



## 2 SCIENTIFIC INVESTIGATIONS IN SPACE

NASA launched six scientific satellites during the second half of 1965—five of the Explorer class and one Orbiting Geophysical Observatory—and prepared the Orbiting Astronomical Observatory for a flight early in 1966.

In July, Mariner IV approached within 6,118 miles of Mars and televised 22 remarkably clear pictures of the planet's heavily cratered surface. High-quality photographs of the moon supplied by the TV cameras of Ranger VII were sent to observatories, universities, and lunar scientists throughout this country and abroad. Surveyor—an unmanned spacecraft designed to soft land on the moon—was scheduled for launching in the spring of 1966.

Lunar Orbiter was also scheduled for a 1966 launch. It will photograph large areas of the moon to provide data to be used in selecting landing sites for manned and unmanned spacecraft. A 140-pound Pioneer spacecraft was launched from Cape Kennedy in December to inaugurate a NASA program for systematically measuring and monitoring interplanetary space during a complete solar cycle. Life scientists selected experiments to be carried aboard the Agency's first Biosatellite—an orbiting biological laboratory planned for launching in the fall of 1966. Its objective is to determine the effects of the space environment on plants, animals, and other life forms to help pinpoint the hazards astronauts may encounter on prolonged space missions.

Project Gemini astronauts took excellent pictures of the earth and its weather from their spacecraft. The terrain pictures were used by geologists, oceanographers, meteorologists, and other scientists. Looking toward the early Apollo missions, NASA contracted for the design of a lunar surface experiments package which an astronaut would use and then leave on the moon to collect data.

### Physics and Astronomy Programs

#### Orbiting Observatories

The Orbiting Geophysical Observatory is one of the most advanced unmanned satellites developed by NASA. The spacecraft, with its 49-foot insectlike booms, is made up of more than 100,000 parts. Its communications system can handle 298 different ground commands and its tape recorders can store 86 million bits of data to be played back at the rate of 128,000 bits a second.

OGO-II was launched on October 14. The first NASA satellite launched by a Thrust-augmented Thor-Agena D, it was placed in a low-altitude, 250-940-mile nearly polar orbit to observe near-earth phenomena. (OGO-I—launched September 4, 1964—was in a highly elliptical orbit to allow it to sweep through interplanetary space measuring magnetic fields and energetic particles outside the earth's magnetosphere.) OGO-II's primary missions are global mapping of the geomagnetic field, determining the composition of the earth's upper atmosphere, and correlating both with solar X-ray and ultraviolet emissions and with airglow.

The second Orbiting Geophysical Observatory was launched after an intensive analysis was made of the failure of OGO-I to stabilize as planned in 1964. (*12th Semiannual Report*, p. 53) The sensors of OGO-II initially stabilized the spacecraft and 19 of the 20 experiments on board returned data. However, its infrared horizon scanners locked on false horizons, apparently high cold clouds, causing the supply of control gas to be depleted. Consequently, the spacecraft lost stabilization in less than 2 weeks and began tumbling. OGO-II's experiments—most of which were designed by universities—were carefully selected to serve as one intensive investigation of the upper atmosphere and ionosphere, the magnetic field, the radiation belts, cosmic rays, micrometeorites, and solar emissions.

OGO-B was made ready to be launched into an elliptical orbit in 1966; it will make studies like those made by OGO-I. OGO-D was being prepared for launching later in 1966 into an orbit similar to that of OGO-II.

OSO-C, planned as the third Orbiting Solar Observatory, was launched on August 25. However, the usually reliable Delta launch

vehicle failed to place it in orbit, apparently because of premature ignition of the third stage. Experiments selected for OSO-C will be flown on OSO-E, being readied for launch in the first half of 1966.

The Orbiting Astronomical Observatory (OAO-A) was also being made ready for launch in 1966, and development and testing of instrumentation for OAO-B proceeded as planned.

### Explorer Satellites

On November 6 NASA launched Explorer XXIX, the first of two geodetic satellites designed to determine the earth's size, shape, and mass, and variations in gravity. Explorer XXIX's instruments provide measurements needed to establish a more exact model of the earth's gravitational field and supply more precise data to be used in mapping long distances. Developed as GEOS-A, Explorer XXIX is a phase of a coordinated U.S. geodetic satellite program involving NASA and the Departments of Commerce and Defense. Ohio State University, the University of California (Los Angeles), and the Smithsonian Astrophysical Observatory also participated in this program. This was the first satellite launched by the improved Delta and one of NASA's first to use the gravity-gradient method of stabilization to keep one of its surfaces pointed toward the earth. Explorer XXIX uses six systems, which rely mainly on radio measurements, to provide worldwide geodesy measurements. The satellite also carries a flashing light beacon for optical tracking and 322 corner reflector prisms for studies in laser beam tracking.

The geodetic satellite program involves extensive international cooperation in ground-based observations and data acquisition. For example, scientists in Finland, France, Greece, the Netherlands, Sweden, the United Kingdom, and West Germany are actively participating in this Explorer XXIX project.

Explorer XXX was launched on November 19 to measure and monitor solar X-ray emissions during the final portion of the 1964-65 International Quiet Sun Year. (Fig. 2-1.) Also called the "IQSX Solar Explorer," it was built by the Naval Research Laboratory and continues solar investigations begun by the laboratory in 1949. The satellite's objectives are to monitor energetic X-ray emissions of the sun and measure the intensity and spectral quality of the emissions during flare development, correlating these measurements with ground-based optical and radio observations. It is the first solar radiation (SOLRAD) type satellite to be spin stabilized.

This Explorer spacecraft is unusual in that it provides immediate data to anyone throughout the world who chooses to receive it. The international scientific community was invited to acquire data directly

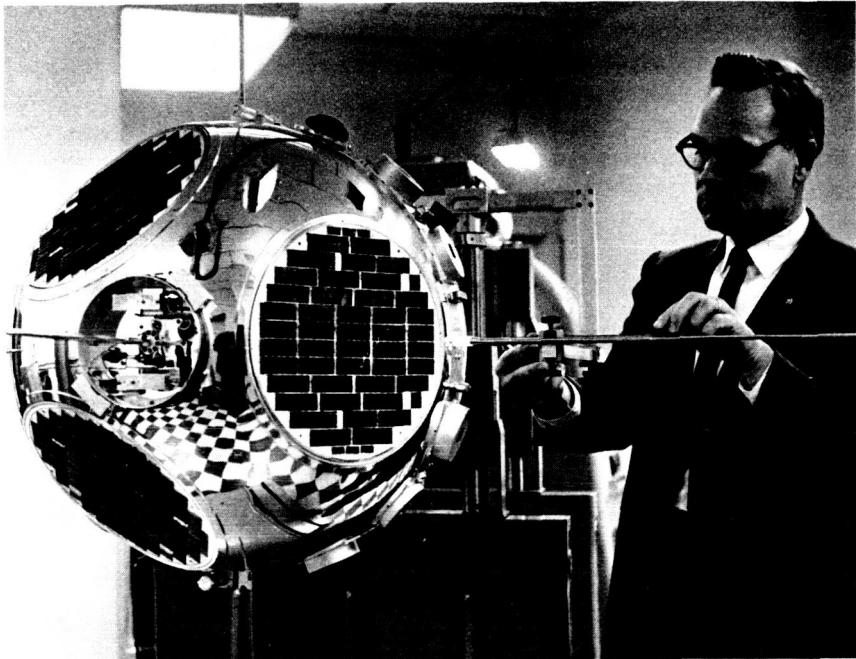


Figure 2-1. Explorer XXX.

from the satellite to be correlated by those participating in the International Quiet Sun Year. This information may be useful in forecasting ionospheric conditions affecting radio communications and in developing a warning system against major solar flares which produce radiation hazardous to men on space flights.

On November 29, two satellites were placed in very similar polar orbits by a single launch vehicle as Project ISIS-X. One was Alouette II—the second Canadian satellite orbited by NASA in a co-operative project of the Agency and the Canadian Defence Research Board—the other NASA's Explorer XXXI. Alouette II (fig. 2-2) continued topside ionospheric soundings begun by Alouette I in September 1962, extending them to polar regions. Explorer XXXI carried eight experiments designed to complement the measurements of the Canadian spacecraft by conducting simultaneous in-flight studies of important ionospheric phenomena. Data obtained will be made available to scientists around the world.

The French-built satellite FR-1, orbited on December 6, is of the Explorer class. The first to be launched in the French-American co-operative program, it was built in France but launched in the United States. One of its two experiments was French designed to measure

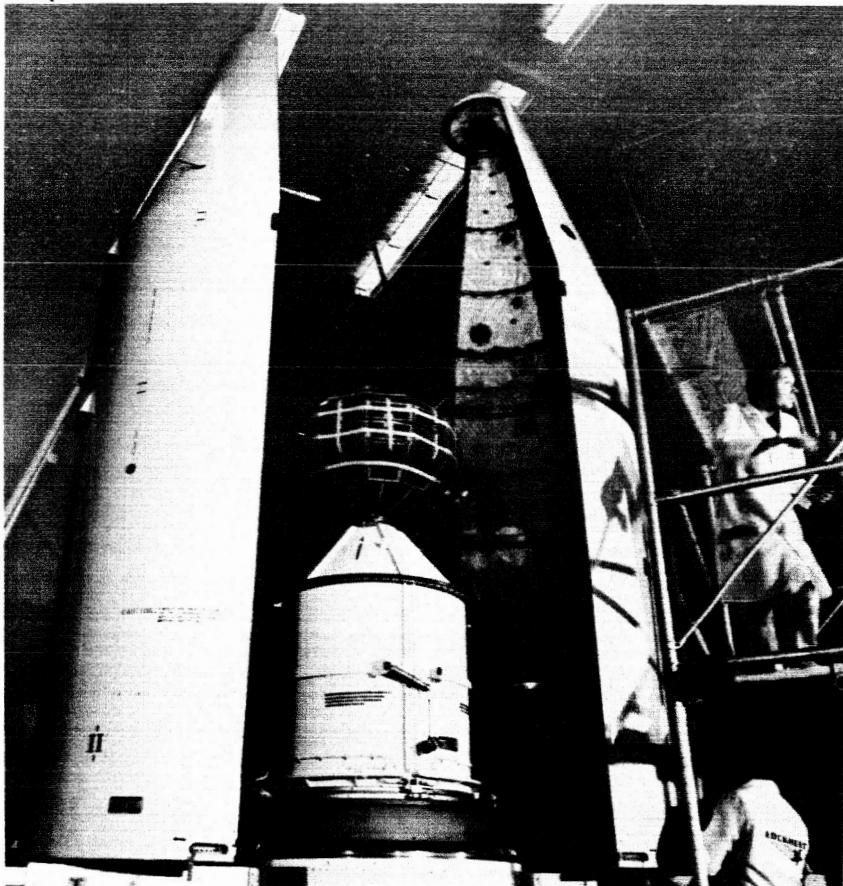


Figure 2-2. Alouette II prototype.

very low frequency (VLF) radiation propagation, and the other was designed by a British investigator to measure electron density near the spacecraft. FR-1 is the second French satellite (the first was A-1 launched on November 26), but the first French scientific satellite

### Sounding Rockets

NASA fired 49 sounding rockets in carrying out studies of winds and temperatures at altitudes up to 60 miles. Investigations were also made of ion and electron densities and energies in the upper atmosphere, characteristics of the airglow, and dust nuclei in high-altitude luminescent clouds. Measurements were made of micrometeoroids or cosmic dust particles. In addition, very low frequency radiation propagation was measured—using the same type of instru-

ment flown later on the French satellite FR-1. In October, sounding rockets took ultraviolet pictures of the Ikeya-Seki comet and photographed the solar corona during passage of the comet. Several rockets were also used to study the plasma near the auroral display, investigate the airglow, and measure the particle flux.

During this report period, several discoveries were made based on the results of earlier rocket flights. For example, neutral helium was found during the day and night at altitudes as low as 60 to 125 miles. An ultraviolet spectrum of the atmosphere of Mars showed a negligible amount of ozone, indicating that solar ultraviolet radiation reaches the surface of the planet. The spectrum also revealed the low pressure of the Martian atmosphere. Preliminary reports from sounding rockets launched from the U.S.N.S. *Croatan* in the western Pacific Ocean in the Southern Hemisphere revealed that an electric current in the upper atmosphere (electrojet) was observed which varied with latitude. Launchings from the *Croatan* also confirmed the presence of high-altitude winds in the Southern Hemisphere.

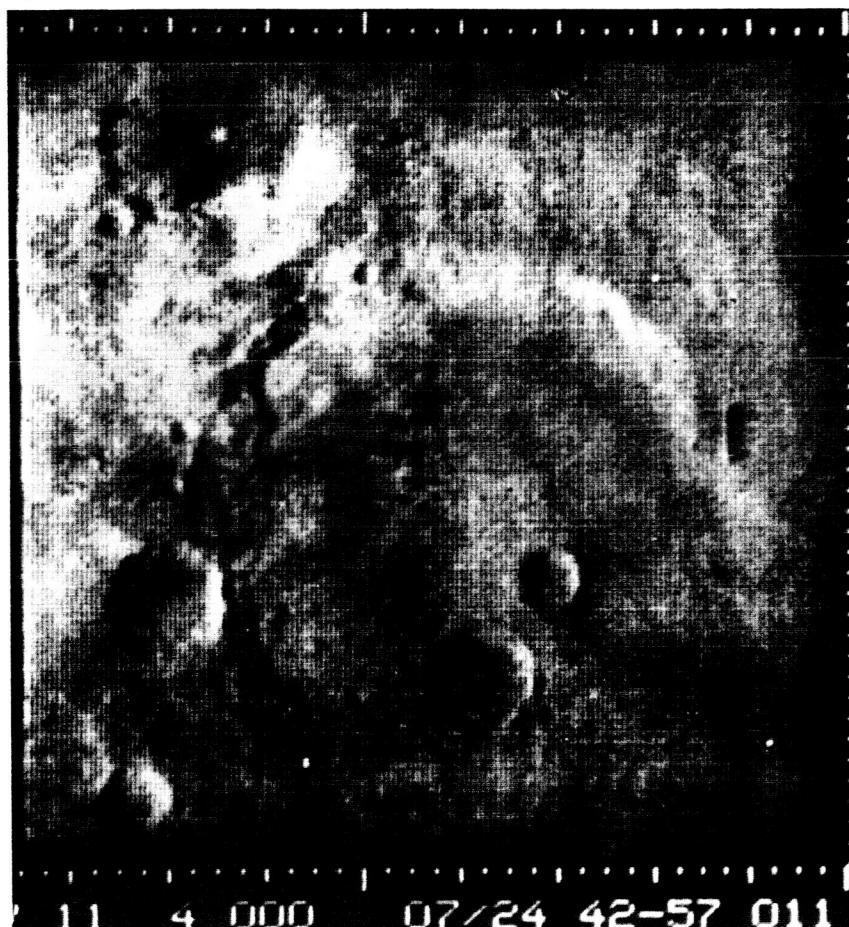
## Lunar and Planetary Programs

### Ranger

The Ranger series is briefly summarized in NASA's *13th Semiannual Report*, page 50. During this period, final reports on the Ranger VIII and IX missions were prepared and copies of the high-quality photographs supplied by Ranger VII were sent to observatories, universities, and lunar scientists in this country and overseas. In addition, about 8,000 bound volumes of these photographs were distributed to American and foreign libraries, scientific laboratories, and research centers. This wide dissemination of the 4,300 pictures should stimulate new research which will greatly increase man's understanding of the nature of the moon. Photographs provided by Rangers VIII and IX were being processed and will be made available to scientists early in 1966.

### Mariner

Mariner IV flew by Mars on July 14, approaching within 6,118 miles of the planet. The spacecraft televised 22 remarkably clear pictures that revealed a heavily cratered surface similar to the moon's. (Fig. 2-3.) Apparently the visible surface is extremely old, geologically. Also, neither a dense atmosphere nor oceans seem to have been present on the planet since these craters were formed. Neither planetary magnetic fields nor radiation belts were detected. The atmospheric surface pressure was found to be approximately 0.5 percent of that at the surface of the earth.



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Figure 2-3. Mariner IV photograph of Mars.

After completing the TV picture playback, Mariner IV continued to transmit data. If still operating in 1967, it may provide about 6 months of interplanetary data as it reaches a minimum distance of 29 million miles from the earth.

#### **Surveyor**

Construction continued on the Surveyor spacecraft which will make soft landings on the moon and transmit high-resolution television pictures of the lunar soil and other data. The spacecraft will survey areas as possible sites for manned landings.

After a thorough review of the Surveyor program NASA has decided to use a 2,200-pound spacecraft to carry out the first seven

missions. This lighter Surveyor (rather than a 2,500-pound spacecraft previously planned for the fifth, sixth, and seventh missions) should be able to provide a substantial amount of the data required for the Apollo manned lunar landing project. Development of the heavier spacecraft, except for certain long leadtime items, was deferred pending further study.

A test vehicle was dropped from a balloon and made a successful descent under its own power through a planned trajectory. The first flight spacecraft was subjected to extensive functional and environmental tests. In addition, special vehicles tested major subsystems and the fabrication and testing of hardware continued. The first Surveyor flight was scheduled for early in the spring of 1966.

#### **Lunar Orbiter**

The Lunar Orbiter is designed to photograph large areas of the moon to obtain topographic data needed for selecting landing sites for manned and unmanned spacecraft. This spacecraft will also make environmental measurements and supply information on the size and shape of the moon. In this period, a complete prototype spacecraft was built and functionally tested, the first two flight spacecraft were being assembled, and ground equipment was built and its checkout essentially finished. Operational computation programs were written, the command and telemetry data handling system integrated into the space flight operations facility, and the first launch scheduled for 1966. In addition, plans for the first Lunar Orbiter mission were completed, and the areas of the moon to be photographed on that mission were selected so as to cover a variety of the lunar surface. Since the choice of areas to be photographed on later missions will be strongly influenced by the results of the initial mission, detailed plans were being made for the rapid evaluation of the photographed areas as potential landing sites. Planning for the extraction of complete topographic information for the selected landing sites was being coordinated with Project Apollo and with the programs of Federal mapping agencies.

#### **Pioneer**

Pioneer VI was successfully launched from Cape Kennedy on December 16, beginning NASA's program to systematically measure and monitor interplanetary space during a complete solar cycle. The 140-pound spin-stabilized spacecraft (fig. 2-4) is designed to transmit data on magnetic fields, solar plasma, energetic particles, and electron density during its orbit around the sun. It should be more than 50 million miles ahead of the earth at the end of its designed 180-day lifetime. Another Pioneer spacecraft was being readied for launch during the third quarter of 1966. It will be launched on a

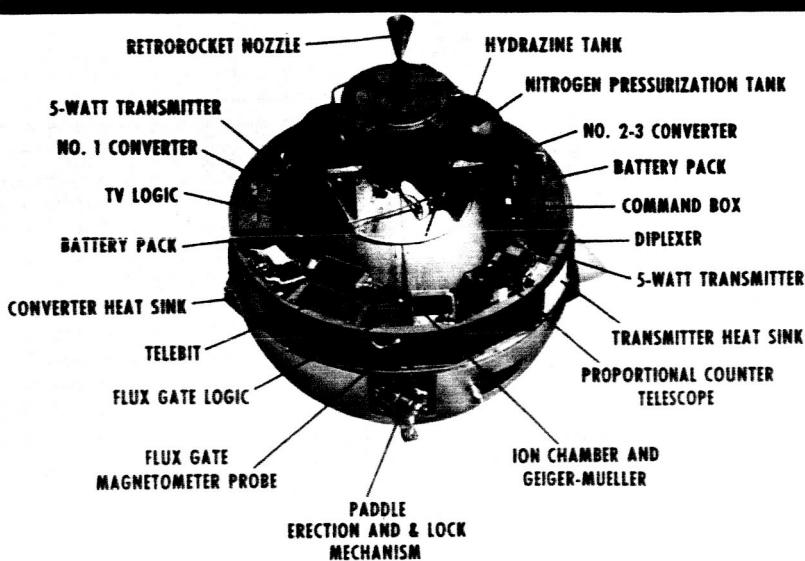


Figure 2-4. Internal view of Pioneer VI.

similar trajectory and will travel in an outward direction away from the earth and sun.

### Voyager

Preliminary design of the Voyager spacecraft was completed on schedule. Its launch vehicle was changed from the Saturn IB-Centaur to the Saturn V to permit the launching of two identical Voyagers by a single launch vehicle. The spacecraft's preliminary design was modified to reflect this change. NASA now plans the first Voyager flight to Mars in 1973, when that planet is closest to the Earth. The spacecraft is designed to obtain data on the existence of extraterrestrial life, supply information on atmospheric and surface characteristics and the environment of the planet, and perform unmanned experiments on the Martian surface.

### Lunar and Planetary Studies

These studies are conducted to determine the feasibility of missions to the moon and to planets, asteroids, and comets and then to plan ways of carrying them out successfully. Recent studies resulted in—

- Substantial progress in developing an advanced computer program called SPARC (Space Research Conic) able to supply quick accurate computations of comet and asteroid ballistic

- swingby, and ballistic swingby with earth-return trajectories.
- An analysis of the feasibility of unmanned scientific missions to certain comets from 1965 through 1986 which concluded that nearly one mission a year to a new comet would be possible if the unique ground support requirements were available.
- An evaluation of a Lunar Orbiter spacecraft for a mission to Mars and return with the conclusion that considerable redesign of the spacecraft might be required and that further study was necessary.
- Determination of typical experiments for a flight to Jupiter and sample scientific objectives for this mission. (Also, study contacts were awarded to evaluate the feasibility of using a Voyager-class spacecraft for such a mission and to study precursor spacecraft concepts for missions to more distant planets.)
- Development of scientific objectives for missions to Saturn, Uranus, Neptune, and Pluto and proposed measuremer's and experiments for these missions.

#### **Advanced Technical Development and Sterilization Program**

The purpose of this program is to anticipate hardware needs of future lunar and planetary missions, and initiate development efforts to provide the improved technology for the designers of these missions. About 70 of these development tasks were conducted in all areas of spacecraft parts and systems. Improved soldering, welding, and assembly techniques for electronic items were studied, and a prototype of an improved planet tracker was successfully tested. The Agency also continued to develop spacecraft hardware able to stand more severe shocks, with some success in mechanical and electrical components. The relative advantages of spacecraft-to earth versus spacecraft-to orbiting satellite-to earth communication were investigated, as were such associated hardware as antennas, receivers, telemeters, transmitters, and batteries. In addition, studies were made of power amplifiers, especially in the 20- to 500-watt range.

The problems of assembling spacecraft systems under bioclean conditions were studied and criteria partially established for designing spacecraft that must be sterilized. Efforts to improve aerodynamic decelerators, such as heat shields and parachutes, for landing capsules were intensified to take into account revised estimates of the atmosphere of Mars resulting from data supplied by Mariner IV. Progress was made in determining the useful lifetime of various spacecraft parts following sterilization. Tests of 175 kinds of polymers used in fabricating these parts showed that about 3 out of 4 commercial varieties (plastics, rubber, and adhesives, for example) withstood the sterilization heat.

## Bioscience Programs

### Exobiology

*Extraterrestrial Life on Mars.*—Scientists of the Space Science Board, National Academy of Sciences-National Research Council, have again recommended that the search for extraterrestrial life on the planets of the solar system—especially Mars—receive the highest priority. (*13th Semiannual Report.*) NASA has considered this recommendation in determining future goals of the Nation's space program.

The Agency's Mariner IV spacecraft transmitted the first photographs of Mars in July. Widespread popular misconceptions resulted from interpretations of these pictures with respect to biological exploration. Based on the degree of resolution required to detect direct evidence of life on Earth, it was confirmed (as predicted) that no such evidence for or against life on Mars was supplied by the spacecraft. A planet with the varying topographical features which Mars apparently has could provide a wide range of environments some of which might be conducive to life. (Mariner IV photographed less than 1 percent of the Martian surface but these pictures revealed altitude differences of 13,000 feet in a single frame.) After careful studies of the Mariner IV photographs, scientists concluded that rather than discouraging further exploration of Mars as a possible site for extraterrestrial life, Mariner IV has given as much encouragement as was reasonable to expect from its design and the purpose of its mission.

*Automated Biological Laboratory.*—Bioscientists have concluded that critical tests for life on Mars can only be made by landing vehicles containing life-detection equipment on the planet. The feasibility of conducting these tests by using an Automated Biological Laboratory (ABL) has undergone intensive study. This laboratory system offers many advantages over the use of several separate detection instruments. For example, biologists are convinced that reliable results can be assured only by using a system able to look for as many characteristics of life as possible at one time, capable of reprogramming its analyses, replicating its experiments, and performing the necessary computations on the data obtained. The system must also be able to select and reduce appropriate data and transmit it to earth. Ideally the ABL could conduct chemical and physical measurements of the planet based on the assumption that life exists there. It would also be able to detect living cells and higher forms of life by using more sophisticated instruments.

Thirty-five experiments were recommended for the first sample ABL payload in a feasibility study recently completed. Typical (but

not the final payload) were such devices as a gas chromatograph, mass spectrometer, infrared spectrometer, radioactive carbon dioxide analyzer, polarimeter, computer object recognition system, fluorometric instruments for enzyme detection, amino acid analyzer, and photosynthesis detection chambers. Many other experiments were in conceptual, laboratory, and test phases. The feasibility study confirmed for biologists that multiple experiments integrated into a single system would be the best approach to the life-detection problem. (Fig. 2-5.)

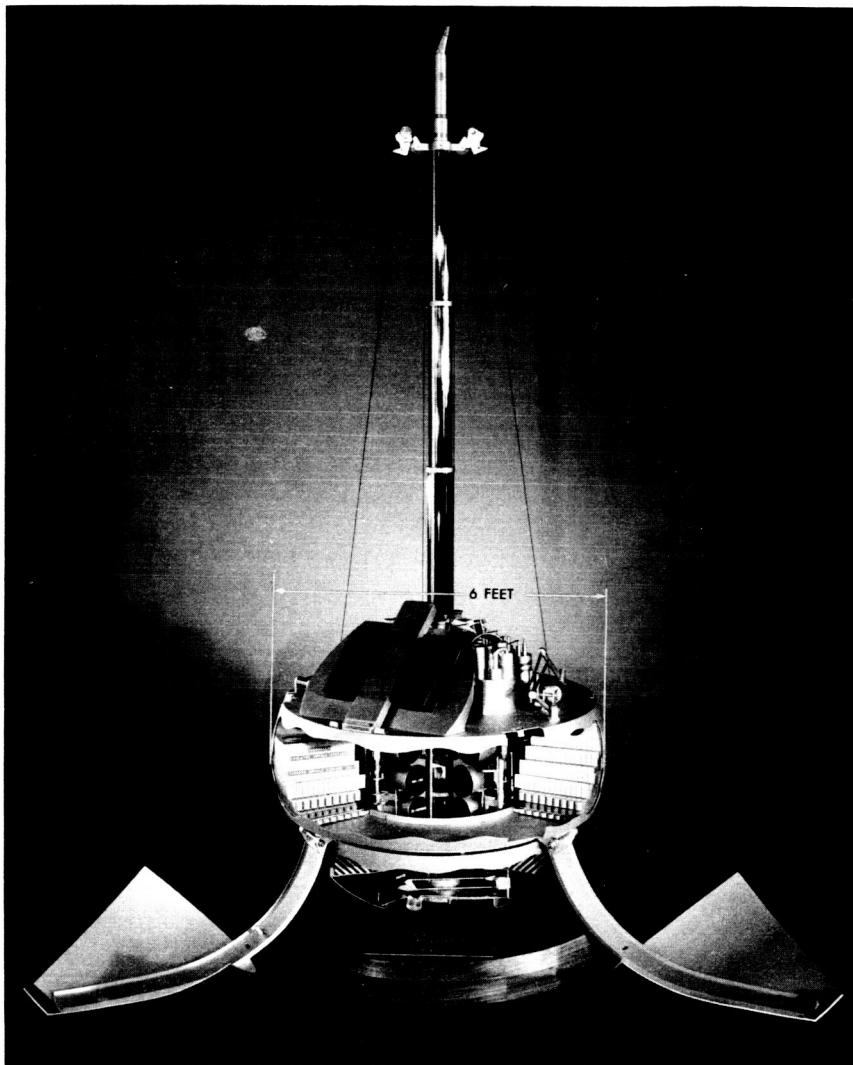


Figure 2-5. Automated Biological Laboratory.

Scientists investigating extraterrestrial life study the earth as a model life-supporting planet. The origin and history of early terrestrial life is studied by analysis of ancient rocks using high-resolution mass spectrometry. (Fig. 2-6.) This method not only reveals

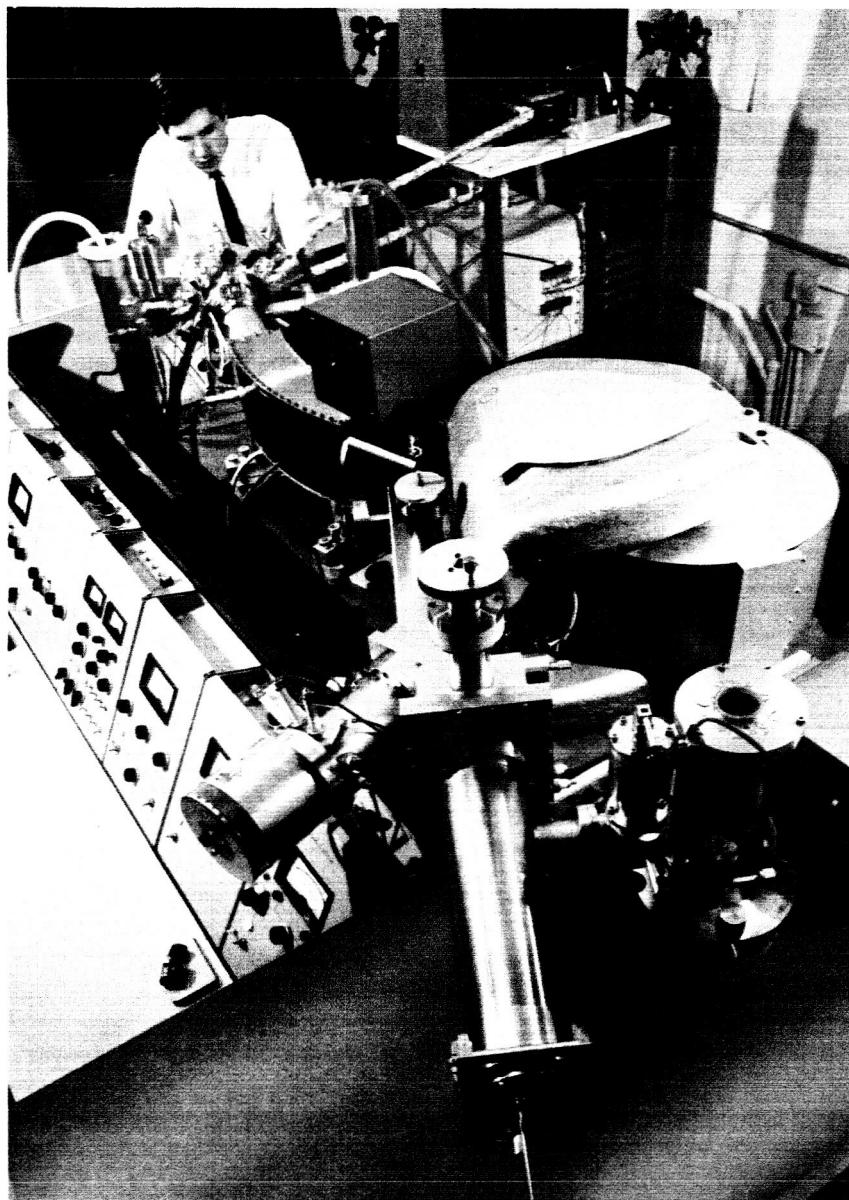


Figure 2-6. High-resolution mass spectrometer.

the presence of life-related chemicals but indicates that the quantities of these chemicals decreases at a rate consistent with the age of the sedimentary rocks. The technique permits the most precise identification of molecules yet possible. For this reason it is considered especially applicable to the geochemical analysis of Apollo lunar samples, analysis of organic matter in meteorites, and the automated analysis of life-related compounds on Mars.

#### **Planetary Quarantine**

Sterility requirements for a spacecraft are much more stringent than those in surgery and in pharmaceutical preparation due to the extreme size and complex design of hardware for planetary missions. (*13th Semiannual Report*, p. 57.) To assure that its lunar and planetary landing spacecraft maintain a low level of contamination by life forms from earth, NASA has enlisted the services of the finest microbiologists in Government, from the universities, and from industry in a planetary quarantine program to develop new sterilization technology.

This planetary quarantine program—established as recommended by the Space Science Board, National Academy of Sciences—prescribes sterilization procedures and is responsible for the supervision and inspection required. These procedures to certify the fabrication and launching of sterile spacecraft were being developed by instructing and training engineers and microbiologists in officially recognized sterility control methods. Microbiological research directed at improving the reliability of the procedures, and at the same time increasing the probability of success for the planetary mission, continued. Also under development was a monitoring and microbiological assessment program for contamination and sterility control to assure that spacecraft will meet sterility requirements for certification for launch. In November, NASA, in cooperation with the California Institute of Technology and the American Institute of Biological Sciences, sponsored the first National Conference on Spacecraft Sterilization Technology.

#### **Biosatellites**

NASA scheduled the launching of its first Biosatellite for the fall of 1966. Thirteen experiments selected for this 3-day flight of the orbiting biological laboratory were in the final stages of testing. When these experiments were subjected to the vibration, acceleration, and shock of simulated space flight, no serious consequences resulted. Seven experiments to study the combined effects of weightlessness and

a known source of radiation showed no significant changes from the simulated space flight and 67 hours of continuous exposure to gamma radiation.

Experiment flight hardware was being fabricated, the Biosatellite spacecraft was undergoing preflight testing, and the flight vehicle for the 3-day mission was being assembled to undergo system tests soon. Test hardware for the experiments to be flown on the 21- and 30-day flights was developed, and individual components and integrated systems were tested.

### **Environmental Biology**

Bone X-ray measurements of Astronauts McDivitt and White during the Gemini IV mission in June suggest that mineral loss during weightlessness may exceed that resulting from earth-based bed-rest studies simulating weightlessness. The apparent loss was recovered shortly after the flight. These studies must rely on preflight and postflight measurements, although newly developed radioisotope techniques show promise for future in-flight use.

New procedures were developed for continuous blood sample monitoring during space flight. The automated system permits blood to be withdrawn and reinjected automatically, determines cardiac output through a dye dilution technique, and measures protein levels. Other automatic systems were devised for conducting chemical analyses of urine during flight. Periodic analyses can be made of calcium, urea, creatine, and creatinine—of general significance to the well-being of the astronaut—for as long as 45 days and the results reported to earth at frequent intervals. Also, knowledge was extended of the environmental extremes under which organisms can survive. Results obtained to date serve to confirm the enormous range of physical and chemical environmental conditions under which living organisms can survive and flourish, and influence the direction of thinking in exobiology and planetary quarantine.

In addition, rapid progress was made in the electrolysis-*Hydrogenomonas* (soil bacteria) bioregenerative life-support system. (*12th Semiannual Report*, p. 64.) This system uses the splitting of water into hydrogen and oxygen by electricity, and the bacteria which combine the hydrogen with carbon dioxide from the astronaut. Continuous culture apparatus was built and tested, and a 20-liter culture constructed for continuous support of one man. In terms of weight, volume, and power requirements this method appears to be several times more efficient than the best algal life-support system.

### **Behavioral Biology**

Since extravehicular activity ("space walks," for example) and other maneuvers require complex behavior, orientation in time and space was under intensive study to help understand and control bodily functions essential to these maneuvers. One technique used by investigators was tracking tasks for astronauts to perform while in a simulated spinning spacecraft or in a decelerating spacecraft during reentry subjected to increasing g-forces. Still to be studied were the speed and limit of adaptation to varying g-forces during the execution of tasks requiring precise control.

Also, during the report period, the development of prospective space experiments with animals was given renewed emphasis. For example, an experiment was developed with pocket mice to show 24-hour rhythms of internal temperature or locomotion changes under certain laboratory conditions.

### **Physical Biology**

Research on dietary requirements has yielded valuable new information in establishing the calories and the amount of protein needed to maintain the health and efficiency of astronauts. Studies on the stability of chemically defined diets at various temperatures and dosage levels of X-irradiation have provided data on storing this type of food during long space missions.

Physical models simulating certain systems of the body were found to be very helpful in establishing the physical laws which operate in biological reactions. For example, such a model of the cardiovascular system used in conjunction with a computer was employed in attempting to determine arterial pressure wave and blood velocity relationships. In addition, new and advanced instruments to measure various biological phenomena were being developed, including an automatic electronic device using computer analysis for scanning, recording, counting, and sorting chromosomes. The information on computer tape may reveal anatomical changes indicating various environmental stress conditions including radiation and possible weightlessness effects.

## **Manned Space Science**

### **Gemini Earth-Orbital Experiments**

Scientific investigations, begun earlier in 1965 with the Gemini III and IV flights, continued with notable success during the Gemini V, VI, and VII missions later in the year. Experiments conducted during the flights included zodiacal light photography, a visual acuity investigation, synoptic photography of the weather and terrain features, and spectrometer measurements of cloud tops.

The zodiacal light—successfully photographed during the Gemini V mission—is a cloudy, hazy, misty light seen in the west after twilight and in the east before dawn. The light is difficult to see or photograph from earth or from balloons because the horizon airglow is sometimes bright enough to mask it out. Another phenomenon photographed during this mission for the first time was the *gegenschein*—a round or elongated spot of light in the sky at a point 180° from the sun.

The visual acuity experiment was performed by Gemini V and VII astronauts. The experiment was planned to determine how well they could make out specific patterns on the ground and whether their ability to see changed during weightlessness. (Fig. 2-7, p. 68.) During Gemini V, cloudy weather limited this experiment. For Gemini VII, the ground observations were successful. On both flights vision tests revealed that the astronauts' eyes were not impaired under the low-gravity conditions during the missions.

The synoptic terrain photography of the Gemini IV, V, VI, and VII flights resulted in excellent pictures (figs. 2-8 and 2-9) which supplement photographic data telemetered to the earth during other types of missions. The astronauts were able to select features to be photographed, assuring the most effective use of the film. The terrain pictures are being used by geologists, oceanographers, and other scientists.

Synoptic weather photography complements the terrain photography by providing pictures covering a broad range of cloud systems. The experiment—carried out for the Commerce Department—uses the same camera and film system as the synoptic terrain photography, with the astronauts selecting areas of interest from weather analyses and TIROS pictures. When feasible, these areas of interest are pointed out to the Gemini astronauts by Mission Control at the Manned Spacecraft Center. These excellent weather photographs are expected to contribute to a better understanding of meteorological satellite pictures and aid in planning instruments for unmanned weather satellites.

#### Apollo Earth-Orbital Experiments

Investigations to be attempted on the early Apollo earth-orbiting missions include synoptic terrain and synoptic weather photography, frog otolith functions, zero-g cell microscopy, trapped radiation particles, X-ray astronomy, micrometeorite collection, ultraviolet stellar astronomy, and soft X-ray (XUV) solar photography. NASA has evaluated proposals and has awarded contracts, or entered into interagency agreements, to develop these experiments.

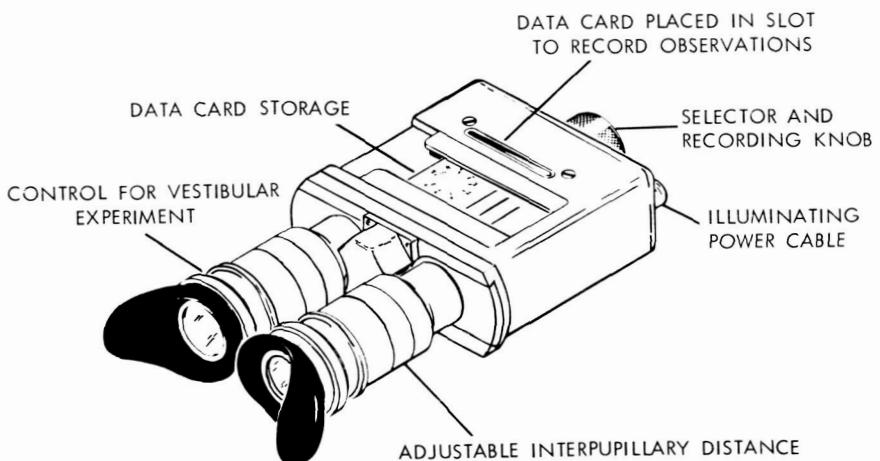
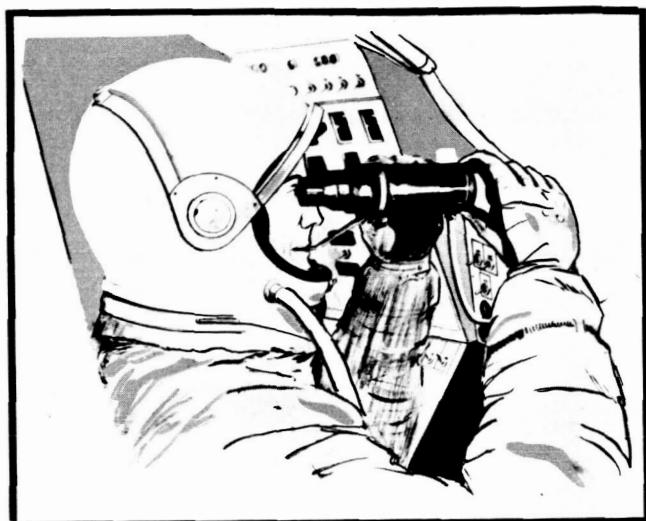


Figure 2-7. Inflight vision tester.

#### Apollo Lunar Science

During the report period considerable progress was made in developing experiments and investigations to be performed in the course of early Apollo lunar landings. These studies will add to man's knowledge of the moon's surface and near-surface features, chemical composition, interior structure, gravitational field, and atmosphere (or lack of it). They will also advance the knowledge of solar wind and the characteristics of radiation near the moon's surface, and contribute to the search for extraterrestrial life.

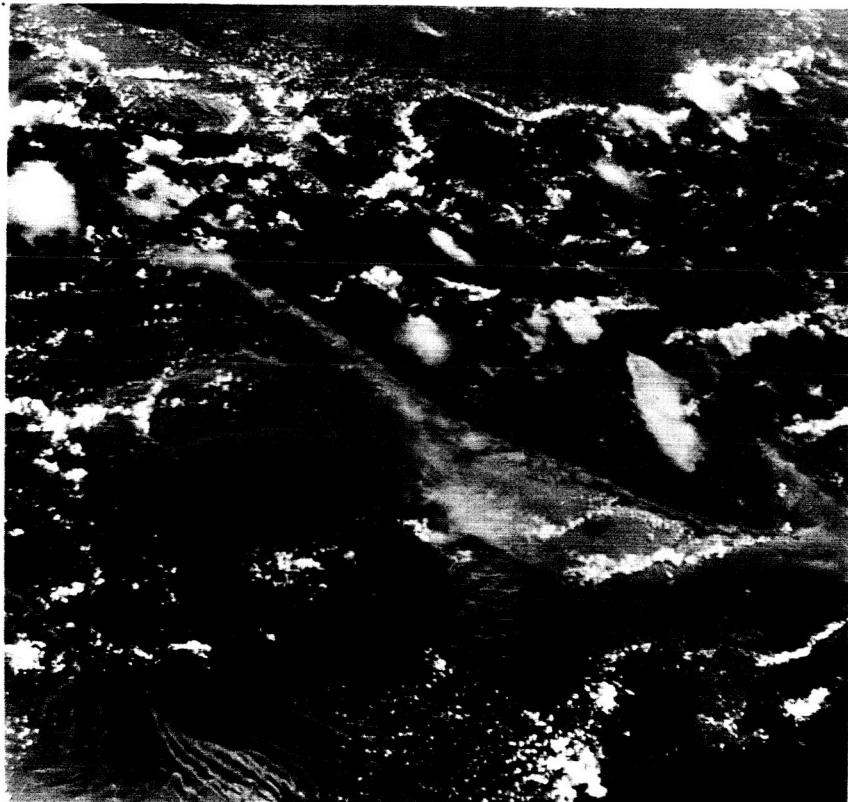


Figure 2-8. The Grand Bahama Bank photographed from Gemini V.

To achieve the prime Apollo scientific goal of collecting the maximum number of uncontaminated samples of typical lunar material, special geological hand tools and sample containers were being designed. While most of these will be adaptations of conventional tools, special problems are presented by the need for virgin preservation of the samples during collection, storage, and handling. Plans were substantially completed for a lunar sample receiving laboratory to receive and unpack the samples, and certify that they are free from pathogens (disease-producing micro-organisms or material) before being distributed to other scientific institutions for analysis.

Many scientists from universities, private research establishments, and Government agencies have proposed a variety of investigations and techniques for lunar sample analysis. To help choose its principal investigators, the Agency plans to have the proposers conduct "dry run" investigations on selected earth materials to test their proposed techniques and procedures.



Figure 2-9. The Florida peninsula photographed from Gemini V

Also of high priority for the early Apollo missions is the Apollo Lunar Surface Experiments Package (ALSEP), an integrated group of compatible geophysical experiments. Contracts for design studies of the ALSEP, which will transmit data for at least a year after an astronaut has erected it on the moon's surface and returned to earth, were awarded by NASA. The system will be automatic, self-contained, and modular in form, allowing changed experiments to be flown on different missions. Since the Apollo flights carrying the ALSEP are expected to be relatively close together, the experiment objectives and lifetime of two or more of these geophysical observatories will overlap to give correlative coverage.

NASA has received excellent cooperation from the Nation's scientists in selecting the most desirable experiments to be placed on the lunar surface in the ALSEP. For the early Apollo flights the field was narrowed to a passive seismometer, active seismometer, magnetom-

eter, gravimeter, suprathermal ion detector, heat flow experiment, and medium- and low-energy solar wind experiments. It is expected that all of these cannot be accommodated in a single ALSEP due to weight and volume limitations. System engineering studies now underway, scientific priorities, and experiment development progress will determine which ones will make up the 150-pound packages.

The passive seismic experiment will detect lunar tremors ("moonquakes"); the active seismic experiment will determine the physical properties of the moon to a depth of about 500 feet. The magnetometer will measure the internal lunar magnetic field and the interaction of the solar wind with the magnetic field around the moon. Temperature and conductivity of the near-lunar subsurface will be measured in the heat-flow experiment. The density, temperature, and rough composition of positive ions in the lunar ionosphere will be measured by the suprathermal ion detector. The medium-energy solar wind experiment is a plasma spectrometer to investigate the velocity and direction of protons, electrons, and alpha particles in the solar wind as they arrive at the moon and the interaction of these particles with the lunar surface. This experiment may also obtain data on the length, breadth, and structure of the earth's magnetospheric tail. The characteristics of electrons and protons in lower energy ranges will be measured by the low-energy solar wind experiment. The gravimeter would measure lunar gravity continuously for several months.

Considerable progress was also made in preparing maps of potential lunar landing areas. Major new emphasis was on producing 1:500,000 scale topographic charts to supply maximum detail based on the best photographic and radar techniques. The maps to be published will provide nearly complete coverage across the lunar equatorial belt—of greatest interest to Apollo manned lunar landings.

At a conference on lunar exploration and science, held by NASA in July, at Falmouth, Mass., participating scientists made recommendations and suggested objectives for the Agency to consider in its advanced manned lunar missions. Investigations were recommended in geodesy, cartography, geology, geochemistry, geophysics, radiation, particles and fields, organic chemistry, and microbiology. Conference results were published as NASA Report SP-88 (app. N). NASA plans to refine and implement these recommendations in cooperation with the scientific community and is funding some definition and preliminary design studies in this field. Also in July, the National Academy of Sciences conducted a space research study at Woods Hole, Mass., which provided NASA with significant space science guidelines and goals for manned missions over the next decade.

## Light and Medium Launch Vehicles

During the last 6 months of 1965 Scout, Delta, Agena, and Atlas-Centaur launch vehicles were used for NASA's unmanned missions.

### Scout

Four Scouts were successfully launched. One orbited a SECOR geodetic satellite for the U.S. Army on August 10; another a Solar Radiation Explorer for the Naval Research Laboratory on November 18. On December 6, a Scout launched the FR-1 in a cooperative program of the United States and France. And, on December 21 still another Scout orbited a spacecraft for the Department of Defense.

### Delta

Delta vehicles successfully orbited three spacecraft in four attempts, and the improvement program to increase the second-stage performance capability of the vehicle resulted in a successful flight.

The first Weather Bureau-funded satellite (TIROS X) was launched on July 2. On August 25, the Delta vehicle failed in an attempt to place an Orbiting Solar Observatory into orbit. The failure resulted from a premature ignition of the third stage of the X-258 solid propellant rocket motor. The improved Delta vehicle was successfully flown for the first time on November 6 when it orbited Explorer XXIX—NASA's first satellite devoted entirely to geodetic studies. In a second flight of this vehicle on December 16, the first of the Pioneer spacecraft was launched.

The Delta launch record at the end of this report period stood at 31 successes in 35 attempts.

### Agena

The second Orbiting Geophysical Observatory (OGO-II) was launched into a low-polar orbit on October 14 in a flight marking several "firsts" for NASA. It was the first Thrust-augmented Thor-Agena flight, the first Agena D liftoff from the Western Test Range (Point Arguello, Calif.), the first radio guidance in the Agena, and the first single-burn Agena mission. Except for radio guidance, the launch vehicle systems performed satisfactorily. Guidance was lost at vehicle liftoff and the entire mission was flown on a backup system, which performed nominally throughout the flight but placed the spacecraft in an orbit slightly higher than that desired.

The Canadian-built Alouette II and NASA's Explorer XXXI were successfully orbited by a single Thor-Agena vehicle on November 29. Launch vehicle performance for this complex mission met all objectives.

Agena vehicle fabrication, manufacturing, and checkout for future missions continued, and several missions were planned for 1966. Assignments included launching an Orbiting Astronomical Observatory, another Orbiting Geophysical Observatory, a Nimbus meteorological satellite, two Lunar Orbiters, and a passive geodetic satellite.

Facilities modifications to Launch Complex 12 at Cape Kennedy completed in December included changes to accommodate the Standard Atlas vehicle and the Orbiting Astronomical Observatory. Modifications began on the Thor-Agena launching pad at the Western Test Range to update equipment and increase its capability to accommodate Delta vehicle launchings. All modifications will be carried out between launches.

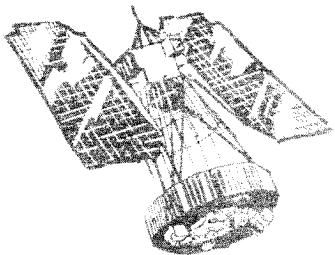
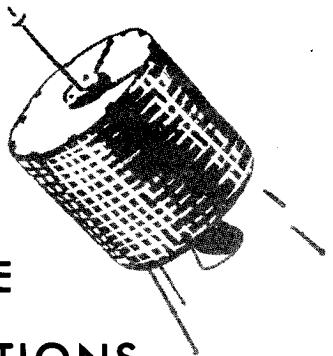
NASA and the Air Force completed preliminary arrangements for a formal transfer of Launch Complex 13 at Cape Kennedy to the Agency early in 1966. Agreements made in the transfer would permit the Air Force to use this complex if necessary.

### Atlas-Centaur

Atlas-Centaur, the Nation's first launch vehicle to use liquid hydrogen as fuel, will be used in lunar and planetary exploration. The first spacecraft it will launch will be Surveyor, the soft lunar lander. The first Surveyor mission (1966) will be flown "direct ascent," a parking orbit (two-burn) capability will be provided during 1966, and additional payload capability will be added in 1967. This vehicle will also launch Mariner for a Mars mission in 1969.

Of the six development vehicles flown, the first flight in May 1962 ended in failure; the next three were generally successful; and a fifth attempt failed at launch. The sixth vehicle, flown in August 1965, was a total success and completed the development program for this "direct ascent" version of the Atlas-Centaur.

## SATELLITE APPLICATIONS



TIROS VII, VIII, IX, and X were in orbit during the last 6 months of 1965, providing weather analysts and forecasters with a constant flow of meteorological data. A photograph of an August hurricane televised by TIROS X alerted officials to the danger of the storm for the Gemini V landing and enabled them to bring the spacecraft down in a safe area.

Pictures taken by the Nimbus I satellite which showed, for example, substantial changes in the geography of Antarctica, proved invaluable to meteorologists, geologists, oceanographers, cartographers, and other scientists. For the second Nimbus spacecraft scheduled to be launched in 1966, NASA was updating its ground equipment and modifying certain ground stations to handle the expected increased volume of information.

In December, the Communications Satellite Corporation's Early Bird demonstrated the expanding role of communications satellites in the Nation's manned space program by supplying live telecasts of Project Gemini recoveries from the deck of an aircraft carrier, and Syncom III, the Department of Defense satellite communications link between the United States and the Far East also joined the Gemini V communications network. In addition, the first of several Applica-

tions Technology Satellites was being prepared for a launch next year. These are part of a project which will include flight experiments in communications, meteorology, and navigation.

### Meteorological Programs

#### TIROS

The TV cameras of TIROS VII and VIII, launched in 1963, continued to provide meteorologically useful cloud pictures. Their successful performance, along with that of TIROS IX (fig. 3-1) and X, permitted uninterrupted use of satellite data for operational purposes. The first two satellites supplemented the cloud data of TIROS IX and X and supplied an average of 4,500 usable pictures monthly from which about 40 cloud analysis maps were prepared and utilized. (TIROS IX did not provide pictures from October until December due to a twilight orbit, but emerged from this orbit in the latter part of December to resume picture taking.)

TIROS X—the first spacecraft funded by the Environmental Science Services Administration—was launched July 2 mainly for coverage during the hurricane season. In an almost perfect sun-synchronous orbit, this satellite is considered the primary one for Weather Bureau operations. Along with TIROS VII, VIII, and IX, it also figured significantly in supporting the Gemini V, VI, and VII missions. For example, a TIROS X photograph of Hurricane Betsy in August (fig. 3-2) provided the basis for the decision to terminate the Gemini V flight early by one orbit. The hurricane is in the lower right corner of the photograph. Its predicted motion and associated cloud system are shown by the shaded area. Since the recovery area for the Gemini spacecraft was dangerously close



Figure 3-1. TIROS IX view of global circulation.

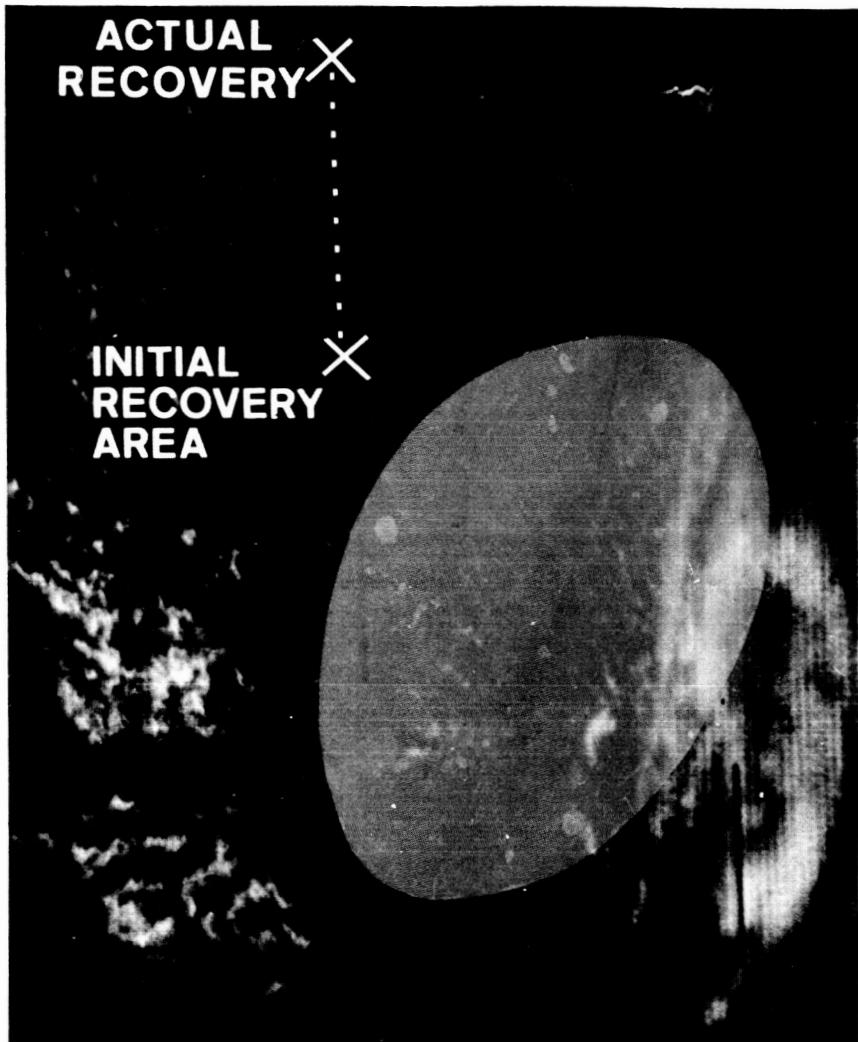


Figure 3-2. The TIROS X photograph of Hurricane Betsy.

to the hurricane's atmospheric circulation, the flight was terminated and splashdown occurred farther north at a safe distance from the storm.

Figure 3-3 summarizes the operational use of TIROS data during the past 5 years, as of December 31, 1965.

*TIROS Operational Satellite System*.—Considerable progress was made in developing and implementing the TIROS Operational Satellite (TOS) System. The initial system uses two wheel-type satellites.

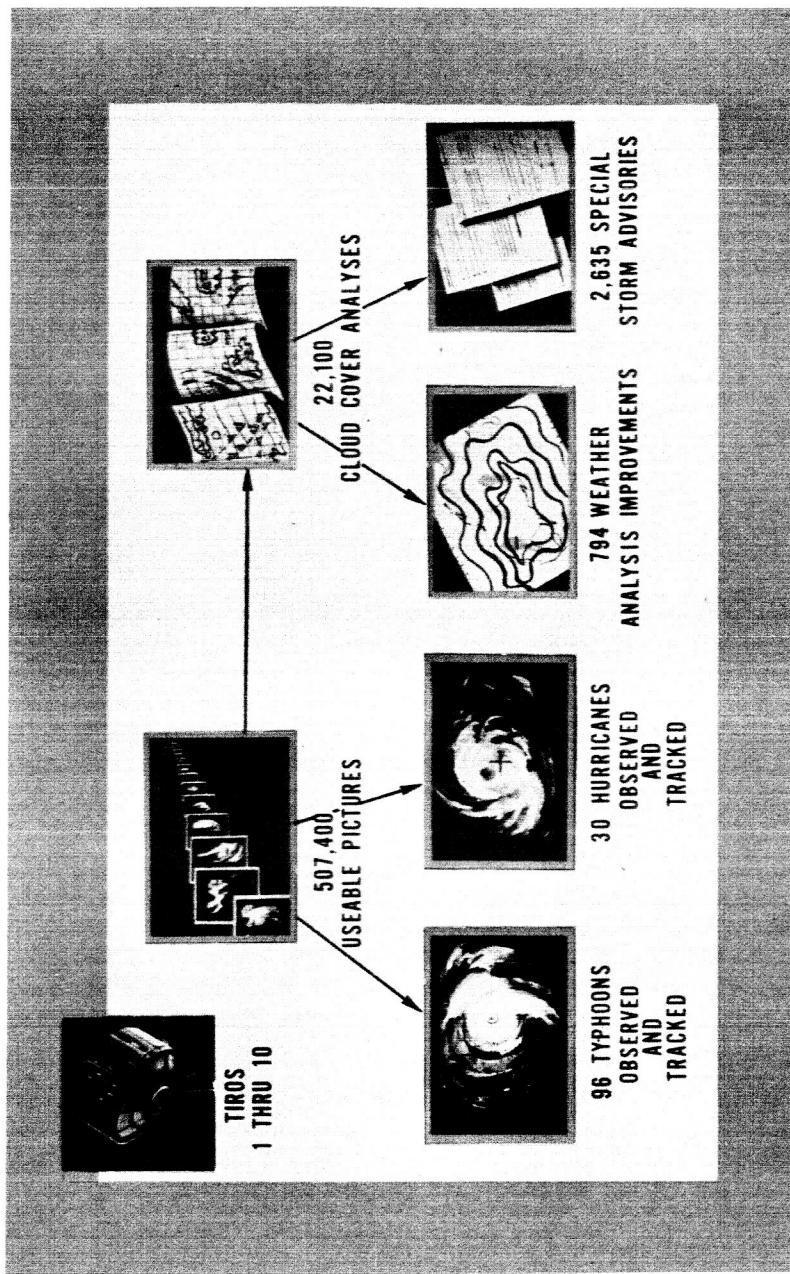


Figure 3-3. Operational use of TIROS data by the Weather Bureau.

One provides local users with automatic picture transmission (APT) pictures; the other furnishes global pictures remotely to the two command and data acquisition (CDA) stations. The remote data received at these stations are immediately transmitted over wide-band communication links to the National Environmental Satellite Center at Suitland, Md. There the data are processed and utilized by the Weather Bureau for daily forecasts and meteorological research and are provided in nearly real time to the Offutt Air Force Base in Nebraska for operational use.

During this report period, the prototype APT and Advanced Vidicon Camera System (AVCS) spacecraft were assembled and qualified. OT-2, the first TOS-APT spacecraft, and OT-3, the first TOS satellite for global cloud coverage, were assembled and qualified for launching early in 1966. In addition, considerable progress was made on the TOS ground facilities, and new communication lines were being installed between the Suitland and CDA stations.

The initial TOS system requires two orbiting satellites to meet the minimum user requirements of direct readout of cloud cover by local APT stations during daylight and full daylight global cloud coverage once daily. Preliminary design of a system was completed to combine the APT and AVCS picture-transmission systems into a single satellite by incorporating a tape recorder into the APT spacecraft to provide stored cloud picture data and local readout of cloud photographs to the APT stations. In addition, work was underway to provide local and global nighttime cloud data on a TOS-type spacecraft. Preliminary design was completed on a TIROS-type spacecraft carrying two high-resolution infrared radiometers like the one successfully flown on Nimbus I. (*12th Semiannual Report*, p. 77.) Also under development were an improved camera requiring less electrical power, an improved radiometer for day and night operation, and a subsystem for onboard gridding of APT pictures.

### Nimbus

NASA made substantial progress in processing, categorizing, and analyzing data supplied by the Nimbus I (launched Aug. 28, 1964) meteorological satellite. The Agency published several catalogs of data for researchers and potential operational users derived from nighttime photofacsimile film strips of 195 orbits of a high-resolution infrared radiometer, about 176 daylight swaths of AVCS cloud pictures, and over 2,000 APT photographs of local cloud conditions. These data substantially advanced knowledge in synoptic meteorology, the atmospheric sciences, glaciology, geology, oceanography, and cartography. In one instance AVCS photographs taken from this spacecraft revealed to the U.S. Geological Survey several marked

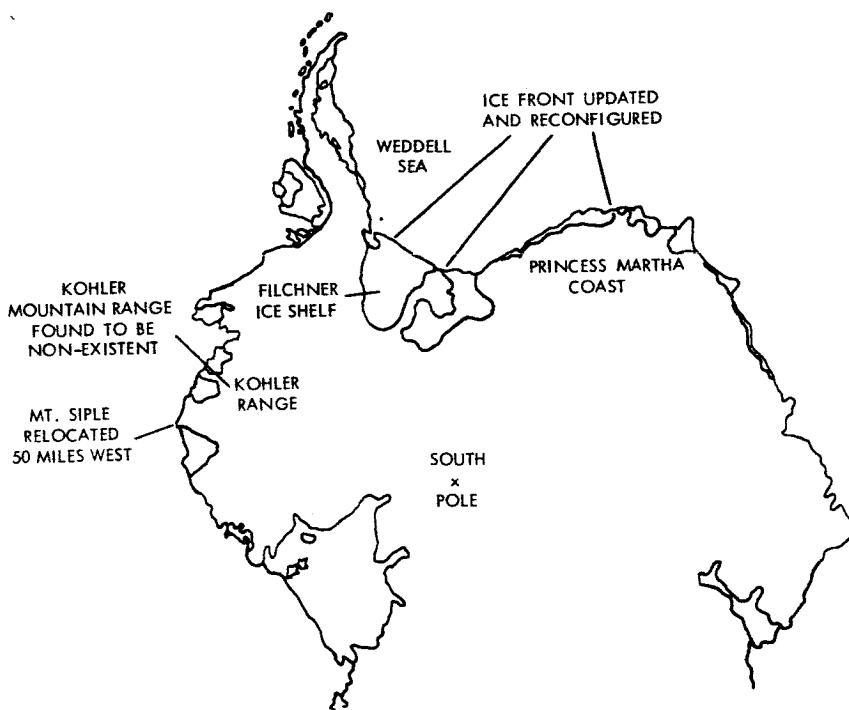


Figure 3-4. Nimbus pictures show changes in Antarctica.

cartographic changes of the Antarctic. (Fig. 3-4.) In addition, Nimbus observations of small-scale cloud patterns, when related to laboratory experiments in forming small-scale circulation cells and vortices, confirmed the validity of the laboratory models.

Significant progress was also made in preparing for the launch of the second Nimbus spacecraft (Nimbus C) in 1966. Major subsystem hardware was delivered, and all preliminary tests were completed on schedule. Component testing of the controls system was completed, and the system was assembled and delivered for electrical and mechanical mating with the flight sensory ring. The solar paddle rotation mechanism which failed in Nimbus I was modified (*12th Semiannual Report*, p. 76), and the redesigned mechanism operated satisfactorily for over 4,000 hours when tested in a simulated space environment.

Ground equipment was being updated and certain stations were being modified to handle the extensive data to be retrieved from Nimbus C. Changes in instruments carried by future Nimbus spacecraft will minimize modifications needed in Automatic Picture Transmission ground stations to enable users to readout local daytime APT pictures and nighttime High-Resolution Infrared Radiometer

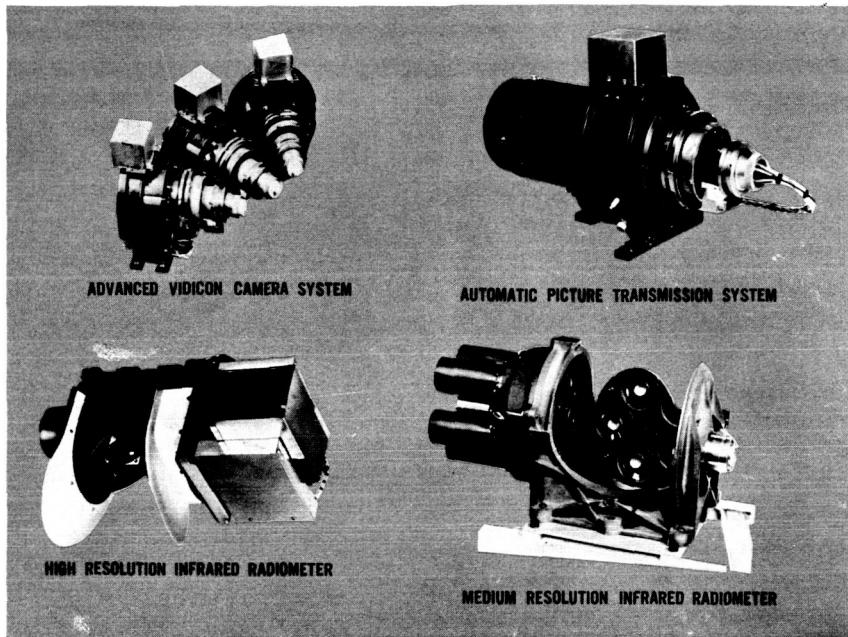


Figure 3-5. Nimbus C sensors.

(HRIR) data. A Medium-Resolution Infrared Radiometer (MRIR) were added to this second Nimbus. (Fig. 3-5.) An improvement of the five-channel radiometer flown in the TIROS series, it is designed to observe the earth's heat balance. The satellite's other sensors—the Automatic Picture Transmission system, Advanced Vidicon Camera system, and High-Resolution Infrared Radiometer—were also assembled and qualified for flight.

A structural model of Nimbus B—the third spacecraft, scheduled for a 1967 launch—was completed and vibration tests of the model begun. In addition, eight unique experiments were approved for the spacecraft to measure the earth's radiation including the ultraviolet and infrared regions. Also, measurements will be made of wind, temperature, density, pressure, and moisture at various altitudes on a global basis through data collection provided by an Interrogation, Recording, and Location system. All of these measurements should help develop the techniques and procedures needed to make accurate weather forecasts up to two weeks in advance. Another Nimbus B experiment will be a radioisotope thermoelectric generator (SNAP-19) to assess the use of this power source for meteorological satellites. (Fig. 3-6.) Since these new Nimbus experiments will require a more

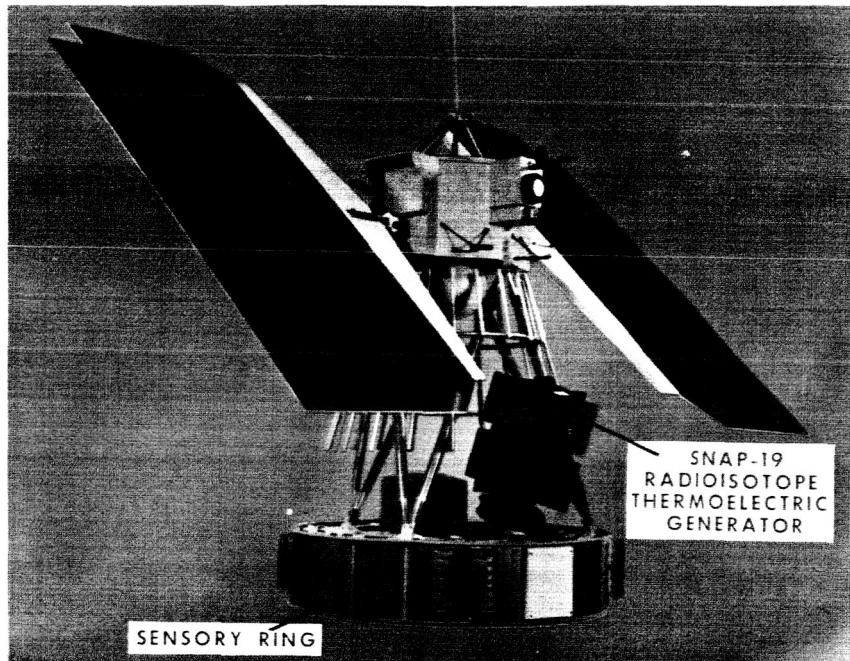


Figure 3-6. Nimbus B radioisotope thermoelectric generator experiment.

powerful booster to orbit the spacecraft, NASA has decided to change the launch vehicle from the Thrust-augmented Thor-Agena to a THORAD-Agena.

#### Meteorological Sounding Rockets

To explore the atmosphere 20 to 60 miles above the earth, NASA used Nike-Cajun and Apache class sounding rockets carrying sodium-vapor, acoustic-grenade, falling-sphere, and pitot-static tube experiments. A continuous ozone-measuring device was being developed for flight testing in 1966. It will measure ozone from a height of 40 miles down to the ozone maximum at an altitude of about 12 miles.

In August grenade experiments were launched from Point Barrow, Alaska, Fort Churchill, Canada, and Wallops Station, Va., to study temperature and wind conditions associated with noctilucent clouds above Point Barrow. The rockets obtained data from the three stations to provide a coarse grid for studying the high-altitude circulation and structure at the time the clouds occurred, as well as local conditions at Point Barrow. The experiments obtained for NASA

scientists the most complete data available to date on these luminous nighttime clouds. During October, the three stations launched additional grenade experiments into the upper atmosphere to obtain data during the transition from the easterly winds of summer to the winter westerly winds.

Routine launches of sounding rockets for range support, research, and network operations require an inexpensive system capable of reliable launches in all kinds of weather. Since small rockets of the Loki and Arcas classes now in use do not meet all these criteria, NASA was improving, developing, and designing rocket motors, sensors, data acquisition systems, and data reduction systems to develop such a sounding rocket network. Flight tests were conducted on high-drag, high-stability payload parachutes, and rockets were subjected to wind tunnel tests to provide performance data. De-spin devices were designed, fabricated, and being readied for flight tests. These devices are planned to eliminate difficulties in deploying parachutes and inflatable spheres from spinning rocket payload sections.

NASA also joined other nations in cooperative sounding rocket programs. For example, the Agency moved toward the establishment of an Experimental Inter-American Meteorological Rocket Network (EXAMETNET) with launching stations extending from southern Argentina to Canada as memorandums of understanding were signed with Brazil and Argentina. (Also discussed on p. 152 EXAMETNET provides for scientists, engineers, and administrators of each participating nation to unite in planning and operating the rocket network and in analyzing the data obtained. NASA hopes that this network may eventually reach from the Arctic to the Antarctic so that similarities and differences of the upper atmosphere of the Northern and Southern Hemispheres may be studied most effectively. The Agency was also considering other stations to join a growing network.

## **Communications and Navigation Programs**

### **Active Communications Satellites**

*Early Bird*.—In December, Early Bird, the first commercial communications satellite, was used to provide live TV coverage of the recoveries of the Gemini VI-A and VII spacecraft from the aircraft carrier *Wasp*. A commercial transportable station installed on the flight deck of the aircraft carrier transmitted pictures of the recoveries to Early Bird; the satellite then relayed them to the Andover, Maine, Station where they were picked up by the television networks. Early Bird, launched by NASA for the Communications Satellite

Corp. in April 1965, ended a period of experimental operation on June 28 when it entered routine commercial service. (*12th Semiannual Report*, p. 76.)

*Telstar.*—Ground stations used in experiments with Telstar (launched by NASA on May 7, 1963) were being converted for commercial service with Early Bird. As a result, although Telstar II worked perfectly during this report period, few experiments were conducted with it since June.

*Relay.*—The operating schedule of Relay II was also curtailed due to conversion of the ground stations to operate with Early Bird. Relay II continued to operate perfectly through ground stations not involved with Early Bird, conducting experiments until September 30, when the only remaining U.S. Relay ground station was taken out of service to be modified for use with the Applications Technology Satellite Project. Relay I has not recovered from the power-supply drain (*13th Semiannual Report*, p. 78) which occurred in February and its useful lifetime was considered to be over.

*Syncom.*—Syncom II and III continued to be used by the Department of Defense for communications between the United States and the Far East. Syncom II has exhausted its on-board propellant supply for stationkeeping but was still usable. (*13th Semiannual Report*, p. 78.) Syncom III—functioning perfectly and positioned over 172° east longitude—was also used as a principal communications link during the Gemini V flight in August.

#### **Passive Communications Satellites**

Echo I and II remained in orbit, but the basic communications experiments for them were completed in 1964. However, these passive satellites were observed periodically to determine their response to the environment. Also, theoretical and laboratory work continued on improved shapes and materials for satellites of this type. (Echo I was launched on Aug. 12, 1960; Echo II, Jan. 25, 1964.)

#### **Navigation Satellites**

The Joint Navigation Satellite Committee—composed of representatives from NASA, the Departments of Treasury, Defense, Interior, and Commerce, and the Federal Aviation Agency—studied the needs of its member agencies for improvements in communications, navigation, air traffic control, and related data transfer.

The Science and Technology Institute of the University of Michigan began an examination of advanced satellite-borne navigation techniques able to provide position information and traffic control data to ships and aircraft.

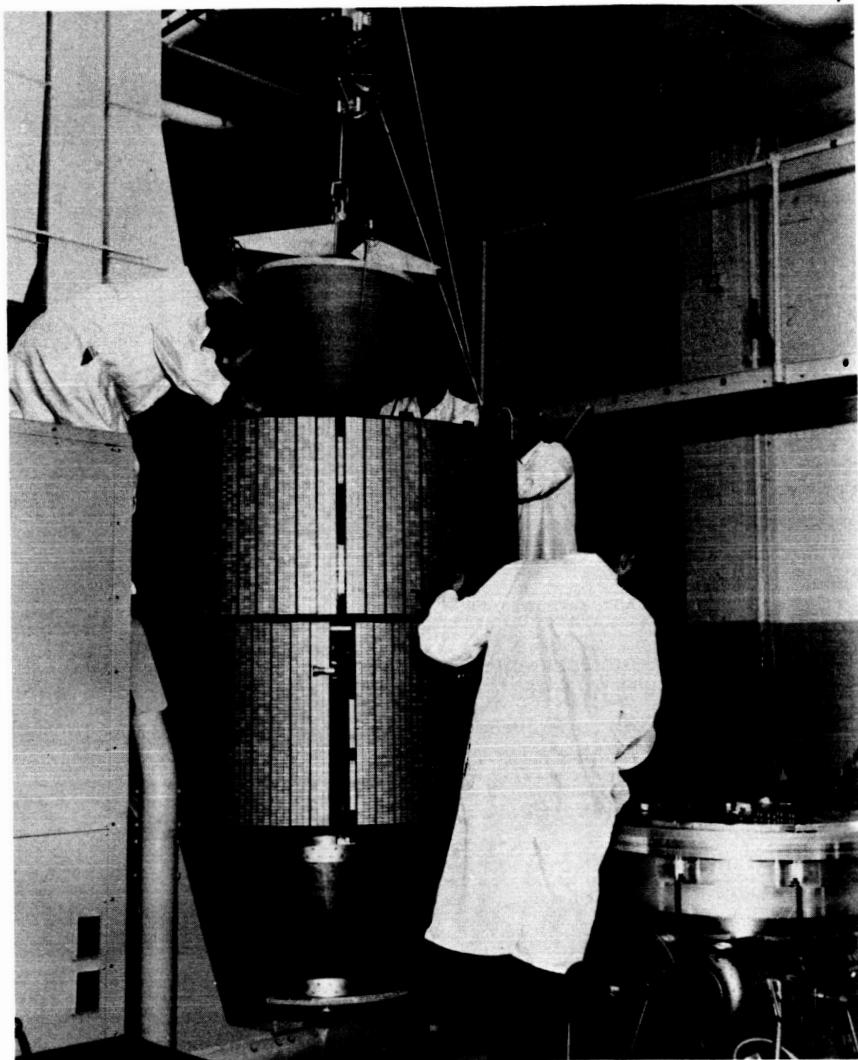


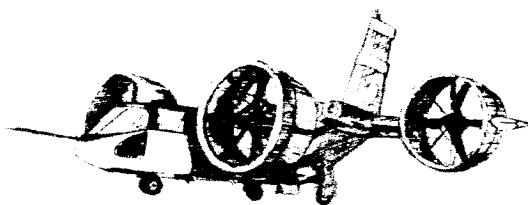
Figure 3-7. Structural model test of ATS-B satellite.

#### Applications Technology Satellites

Structural models of the spin-stabilized version of the Applications Technology Satellite were completed and final assembly of the prototype model began. The satellite (ATS-B) is scheduled to be launched late in 1966. (Fig. 3-7.) The design for the gravity-stabilized satellite and the prototype models of its experiments were completed, and the spacecraft was scheduled for the second launch of the ATS project.

# 4

# ADVANCED RESEARCH AND TECHNOLOGY



The Office of Advanced Research and Technology continued to advance the many projects which fall within the scope of its responsibility. The discussions which follow describe these tasks and indicate their importance to present space and aeronautical programs and their influence upon the Nation's future progress and leadership in aerospace endeavors.

## Space Vehicles Program

### High-Energy Radiation Effects

Newly developed and promising spacecraft materials and components were investigated for susceptibility to damage from space radiation. At the Langley Research Center, research on the fundamental mechanisms involved in radiation damage resulted in significantly improved semiconductor strain gages. Gages irradiated by high energy electrons, under controlled conditions, were 20 times less sensitive to temperature changes. Similarly, a Langley contractor's test program showed that currently available silicon transistors can withstand two to six times the amount of radiation flux previously believed possible. Still another contractor developed improved transistors which are expected to increase the reliability and operating life of future spacecraft in the space environment.

The NASA Space Radiation Effects Laboratory, Newport News, Va., was dedicated December 15, 1965. (Fig. 4-1.) It is equipped with a 600-million-electron-volt synchrocyclotron and associated equipment which will enable NASA to make simulated tests and fundamental studies of the effect of space radiation on spacecraft and their subsystems. The Laboratory, which will be managed and operated for the Langley Research Center and NASA by the Virginia Associated Research Center, a joint venture of the College of William and Mary, the University of Virginia, and the Virginia Polytechnic Institute, will also support university-conducted basic research programs in high-energy physics and radiobiology.

#### **Thermal Radiation and Temperature Control**

To speed up the thermal design of complex spacecraft and to capitalize on the fact that smaller facilities minimize departures from true solar simulation, a one-half-scale thermal model of the Mariner spacecraft was built and tested in a relatively small simulation chamber. The thermal performance predicted in the simulation was compared with that obtained in the actual Mariner IV flight. The results indicated that thermal testing under equilibrium conditions with one-half-scale models is feasible and could materially reduce requirements for large solar simulation facilities. Accelerated studies were begun to develop such techniques for the transient thermal conditions of an orbiting spacecraft whose environment alternates between full sunlight and darkness. Another problem in solar simulation using large test chambers relates to the inadequacy of instruments for monitoring the solar beam. In efforts to overcome the problem, research conducted on thin metallic cones surrounded by resistance heaters indicated the possibility of achieving a basic or absolute measure of the thermal radiation balance of a surface exposed to various thermal test environments.

A new silicate paint was developed which may be useful as a thermal control and space radiator coating in place of white paints currently used to achieve quantitative thermal balance of spacecraft. (The latter are unsatisfactory because they continue to show increases in solar absorptance when exposed to space radiation.) In addition to its space uses, the new coating seemed to have potential as a low-cost white paint for everyday earthbound applications.

#### **Vacuum Technology**

Research on the problem of backstreaming and contamination from oil diffusion pumps continued. Two approaches were under study: prevention of oil backstreaming and development of alternative pumping methods. One promising preventive method used heaters to

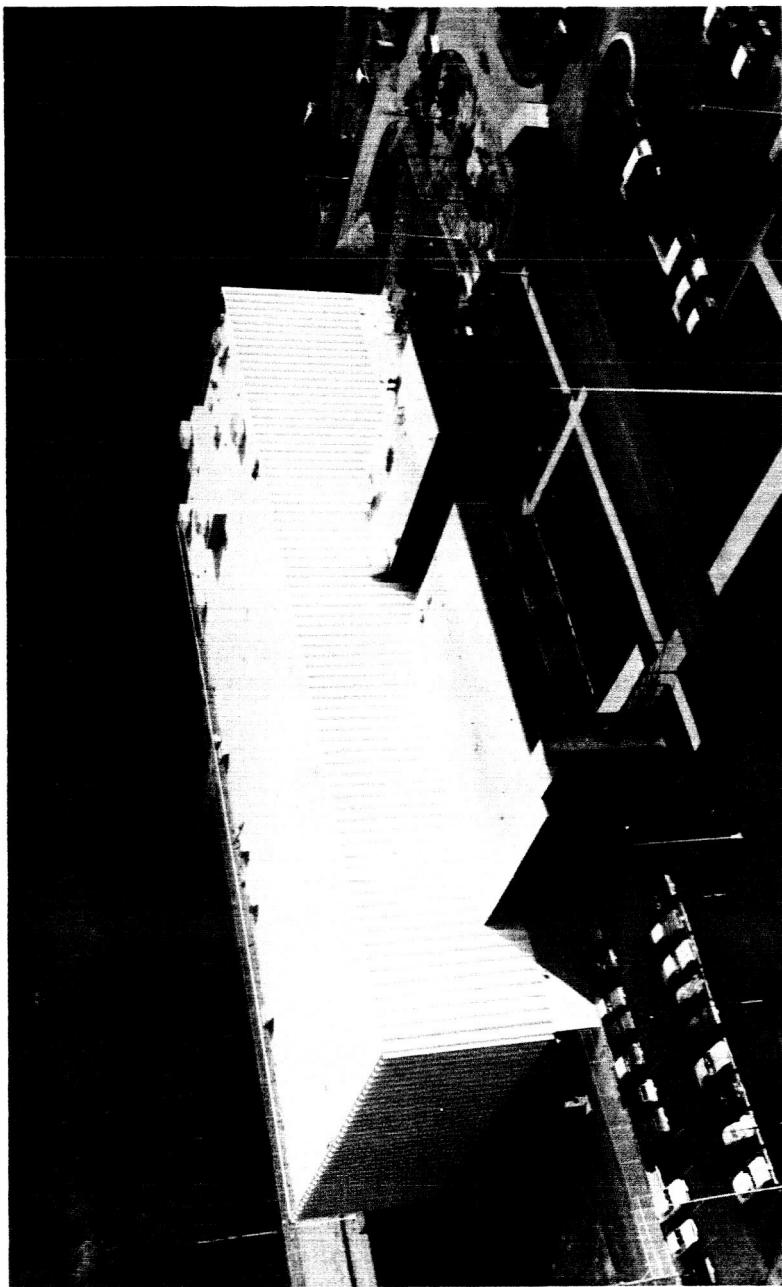


Figure 4-1. The NASA Space Radiation Effects Laboratory.

crack the backstreaming oil molecules, thus aiding in their removal. Other pumping methods tested demonstrated that a pump consisting of a series of rotating turbine blades can also reduce backstreaming.

### Meteoroid Technology

Pegasus III, the third and last Meteoroid Technology Satellite, was launched July 30 by a Saturn I launch vehicle (SA-10) and injected into a near-circular orbit. (Fig. 4-2.) Its primary objective is to provide additional data on the near-earth meteoroid environment for direct application to spacecraft design.

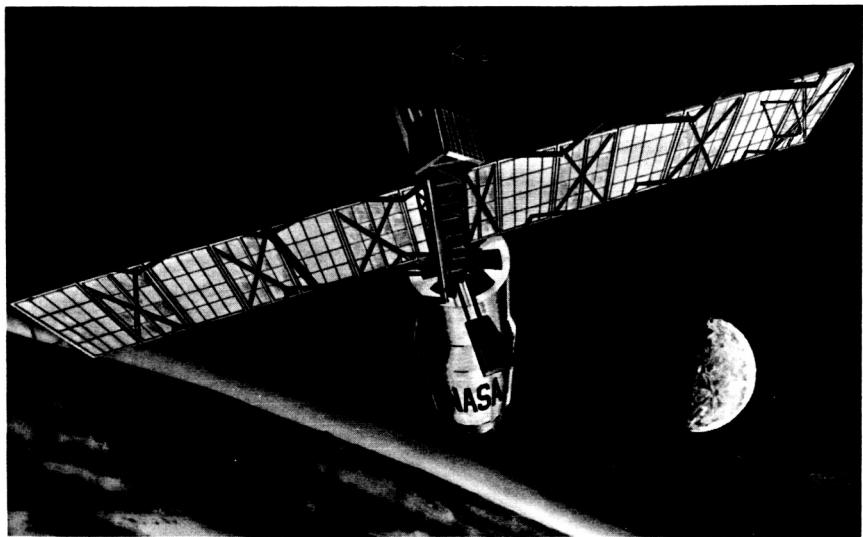


Figure 4-2. Sketch of deployed Pegasus III.

Spacecraft configuration was identical to that of Pegasus I and II with 416 capacitor-type meteoroid sensors mounted in a winglike structure deployed after injection into orbit, over 2,000 square feet of meteoroid penetration sensor area, and three thicknesses of aluminum exposed to the meteoroid environment: 0.0015 inch, 0.008 inch, and 0.016 inch.

The three Pegasus spacecraft launched this year have recorded more than 500 penetrations, with the penetration rates for all three thicknesses of aluminum falling below the rate for the meteoroid environment model currently used for spacecraft design. Explorer XXIII, (*12th Semiannual Report*, p. 91) a much smaller meteoroid technology satellite with thinner penetration test surfaces, continued to function satisfactorily and to provide additional information after a year in space.

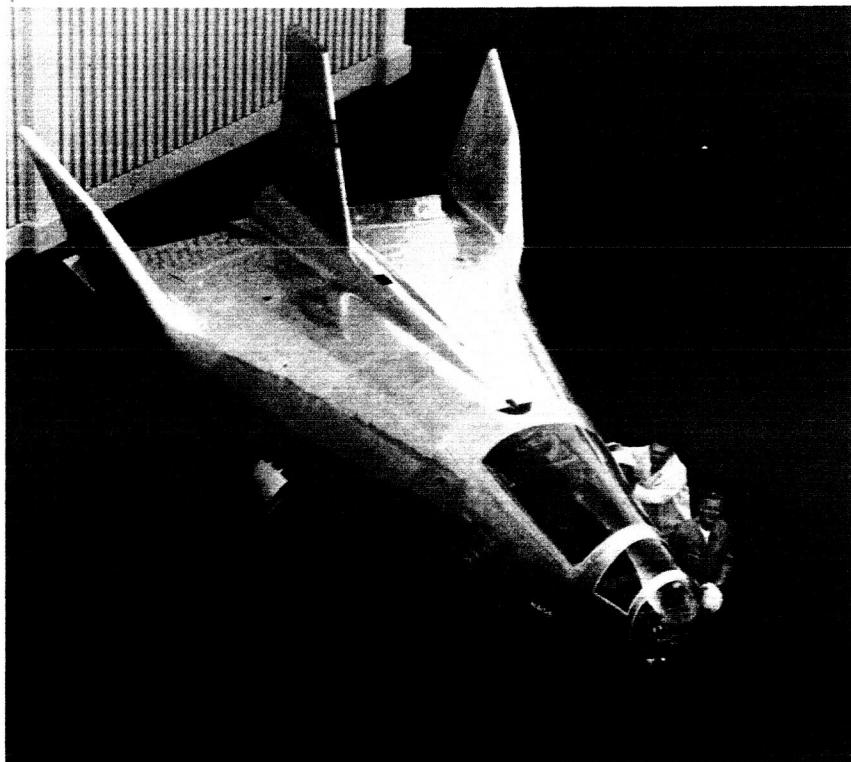


Figure 4-3. The HL-10.

#### Lifting Body Spacecraft

With completion of the HL-10 (fig. 4-3) during this period, NASA has two lifting body research vehicles with realistic spacecraft weights. These conceptually different unpowered vehicles, the M-2 and the HL-10, will be launched from a mother airplane and maneuvered back to earth to determine their handling characteristics, particularly in the critical terminal approach and landing phases of flight.

The M-2 vehicle (*13th Semiannual Report*, p. 87) was tested in the Ames 40- by 80-foot wind tunnel, and the aerodynamic characteristics predicted from earlier small-scale wind tunnel model tests were verified and refined. The preflight checkout of the vehicle was completed at the Flight Research Center, and the vehicle was approved for flight. However, the flight program will be delayed until the lakebed used as the landing strip dries out at the end of the rainy season, which is normally in the early spring.

The HL-10 vehicle will be delivered in January 1966. Following full-scale wind tunnel tests and checkout, its flight program is expected to begin in the early summer.

#### Parachute Technology

NASA continued its search for more versatile and efficient ways to land manned spacecraft. One concept under study is the "limp paraglider," a lightweight triangular parachutelike device that can be packed and deployed like a conventional parachute. (Fig. 4-4.)

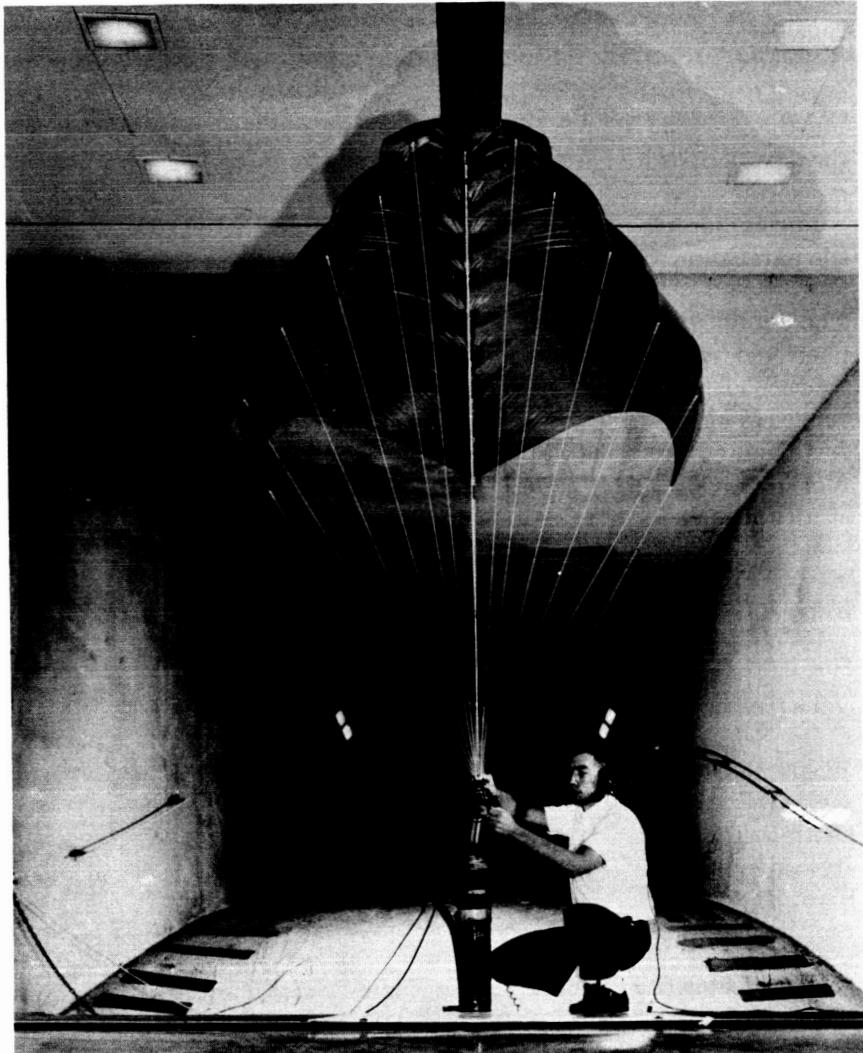


Figure 4-4. Model of limp paraglider.

Once deployed, the limp paraglider allows an astronaut to maneuver his spacecraft within an area of several hundred square miles in order to select the best landing site or to overcome surface winds. The Langley Research Center completed preliminary wind tunnel tests on small models and made free-flight tests on somewhat larger models to investigate deployment and flight performance characteristics. The limp paraglider offers potential reliability close to that of the already proven conventional parachute, the ability to provide low vertical velocities at touchdown, and the possibility of landing on either land or water. In addition, its large maneuverability "footprint" makes it considerably more versatile than a conventional parachute. With these advantages, the limp paraglider might be used by high-performance lifting-body type spacecraft as a subsonic landing aid eliminating the need to compromise the hypersonic design characteristics of the spacecraft for low-speed flight. It may also be used to give maneuverability at low altitudes to present types of spacecraft.

For exploration of such near planets as Mars, a lightweight, versatile parachute, more conventional in appearance, may be used to retard the descent of instrument capsules into the very thin atmosphere. The Langley Research Center investigated a parachute for atmospheric soundings in the very low density of the earth's atmosphere above 150,000 feet. The "disk-gap-band" parachute makes use of extensive open areas, or large-scale porosity, in the parachute canopy for a more stable descent. (Fig. 4-5.) Recent rocket tests on 15-foot diameter disk-gap-band parachutes indicated good performance at altitudes as high as 200,000 feet. Because the atmospheric conditions near the surface of Mars are similar to those at altitudes over 100,000 feet above the earth, the disk-gap-band parachute appears to be a good candidate for Mars applications.

#### **Fire II Reentry Heating Experiment**

The second and last experiment in Project Fire, flown May 22 (*13th Semiannual Report*, p. 92), provided significant information on spacecraft aerothermodynamics. The experiment determined very accurately the peak heat load due to the radiative and convective heating processes for a blunt ballistic type vehicle entering the earth's atmosphere at lunar return speeds. Together, the two Project Fire flight experiments effectively defined the earth heating environment for Apollo reentry.

#### **Advanced Structures Concepts**

Lunar and planetary exploration will require shelters on the surface of the moon and planets to allow men to leave and live independently

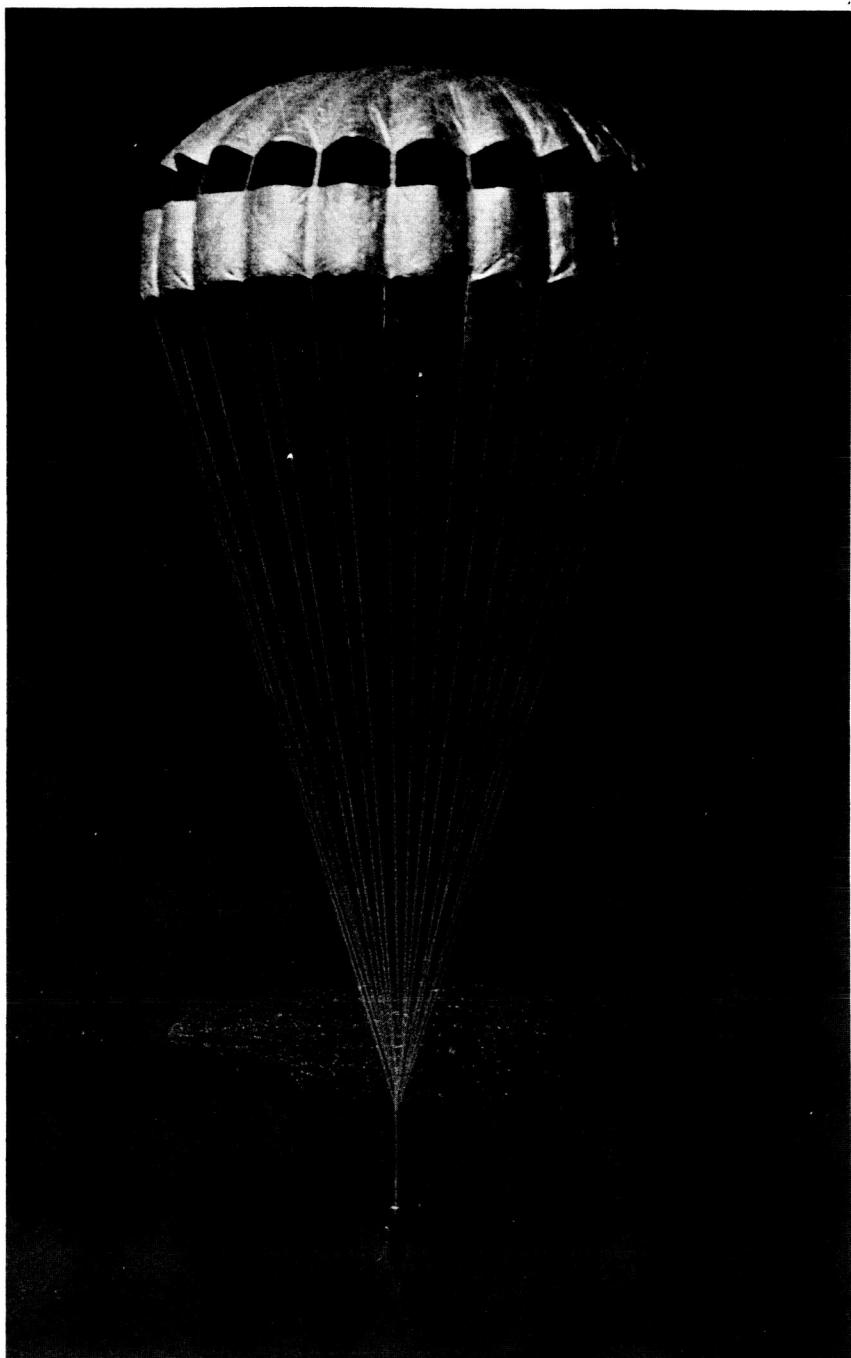


Figure 4-5. A disk-gap-band parachute.

of the landing vehicles. To investigate structures for this purpose, NASA selected a hypothetical mission using the present lunar module without basic modification to transport two men and a shelter to the surface of the moon. Research programs on filament winding, thermal control coatings, meteroid penetration, and expandable structures developed the advanced technology used in the design and construction of a shelter module which can be packaged in less than 75 cubic feet and weighs only 326 pounds on earth. It expands to provide an enclosed volume of 505 cubic feet, including an integral air lock. The shelter can deploy itself after unpacking, because of the multiple layer construction of its wall, and it can be handled easily by a single astronaut. (Fig. 4-6.) The interior can accommodate all facilities to support two men in a shirt-sleeve environment for 8 days. The packaged volume of the shelter is small enough so that it can be carried to the moon by a lunar module in external canisters. Studies were continued on similar structures suitable for more men for longer periods.

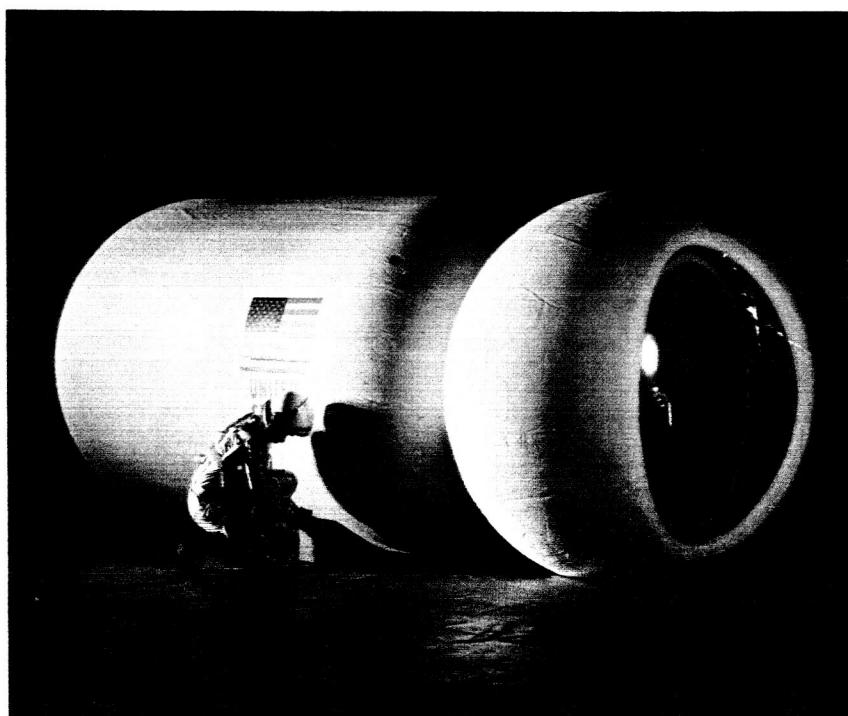


Figure 4-6. An expandable shelter.

### Structural Mechanics

Many structural engineering problems concerned with the integrity of solid propellants or the deformation of highly heated metals can be reduced to the stress analysis of viscoelastic materials (those exhibiting both fluid and solid behavior). However, research on viscoelasticity has been quite difficult because reliable experimental methods were not available. A newly developed experimental technique for use with such materials is therefore a significant advance in this field. The technique calls for modified optical test equipment and an optically transparent viscoelastic model. Under load, the model shows dark lines connecting points of equal stress difference. The growth and behavior of the lines is recorded photographically and provides data necessary to determine the instantaneous state of stress. The same method can be used to study transient stresses of thermal origin, and the developed equipment and techniques were being refined for routine use in engineering analysis and design.

### Structural Dynamics

The lateral vibration characteristics of space vehicles affect control system design parameters, the location of control system sensors, the interaction of vehicle and propellant motions which affect the stability and loading of the vehicle, and the determination of dynamic loads and stresses. These characteristics are usually determined theoretically and revised following vibration tests on the full-scale vehicle. However, with current large launch vehicles it is difficult and expensive to suspend and vibrate a full-scale vehicle. Consequently, NASA investigated the use of reduced size models, and completed vibration tests on one-tenth and one-fortieth scale models of the Saturn V. (Fig. 4-7.) For a booster half filled with propellant (an average flight condition), the lateral vibration frequencies for the one-fortieth scale model were only 6, 9, and 8 percent higher in the first three natural frequencies than the corresponding frequencies of the one-tenth scale model. The tests on the two different sized models seem to indicate that prescribed vibration characteristics can be designed into two models having very different type construction. The tests also increased understanding of the relationship of rigidity in areas of structural complexity to the design of the vehicle structure and control systems.

## Spacecraft Electronics and Control

### Control and Stabilization

The Flight Research Center continued research and development work on fluid controls as part of NASA's control system program.

Fluid technology is under investigation as a source of an economical, reliable, and efficient aircraft flight control system in which a moving fluid replaces conventional electronics as the information medium. A contractor was selected to study system concepts and identify component requirements for an autopilot system for light aircraft. The results of the preliminary investigation indicated that a prototype control system can be defined, and fabrication of a breadboard model for further study was begun. The successful development of fluid technology should aid materially in achieving an advanced control system at a price compatible with that of the airplane. Other applications of all-fluid technology were also being investigated.

#### Guidance and Navigation

A feasibility model of an optical (laser) rendezvous radar was developed, laboratory tested, and demonstrated at the Marshall Space Flight Center. An improved prototype model, which is expected to outperform the feasibility model in range and angular accuracy by a factor of 4, was being developed. System operating ranges beyond 100 kilometers and angular accuracies of  $0.01^\circ$  are realizable, and by selection of operating modes, the system appears to be able to function accurately down to zero (or docking) range. The development program will produce a flight test model which can be demonstrated in earth-orbital experiments.

With rendezvous and docking becoming a key function in space, guidance equipment will have to use the most efficacious techniques possible and be characterized by simplicity and reliability. Optical and laser techniques seem to satisfy these requirements inasmuch as they offer these advantages over alternate methods: Lighter weight; less volume; less input power; simplicity; and greater angular accuracies, all resulting from the tremendous antenna gains obtainable with laser systems.

#### Communications and Tracking

A 20-watt S-band microwave transmitter similar in size and weight to the Mariner IV 10-watt tube but with double the Mariner  $8\frac{1}{2}$ -bit-per-second data rate capability was developed, and 9 were ordered for the Saturn V Command Communications System. Plans were formulated to develop the technology for larger space-rated, 500 to 1,000 watt tubes which will increase the data rate capability over Mariner IV 100 times.

Ground antenna array studies were completed for Langley Research Center and Goddard Space Flight Center (GSFC). An experiment was formulated for arraying two 15-foot antennas at GSFC as a basis

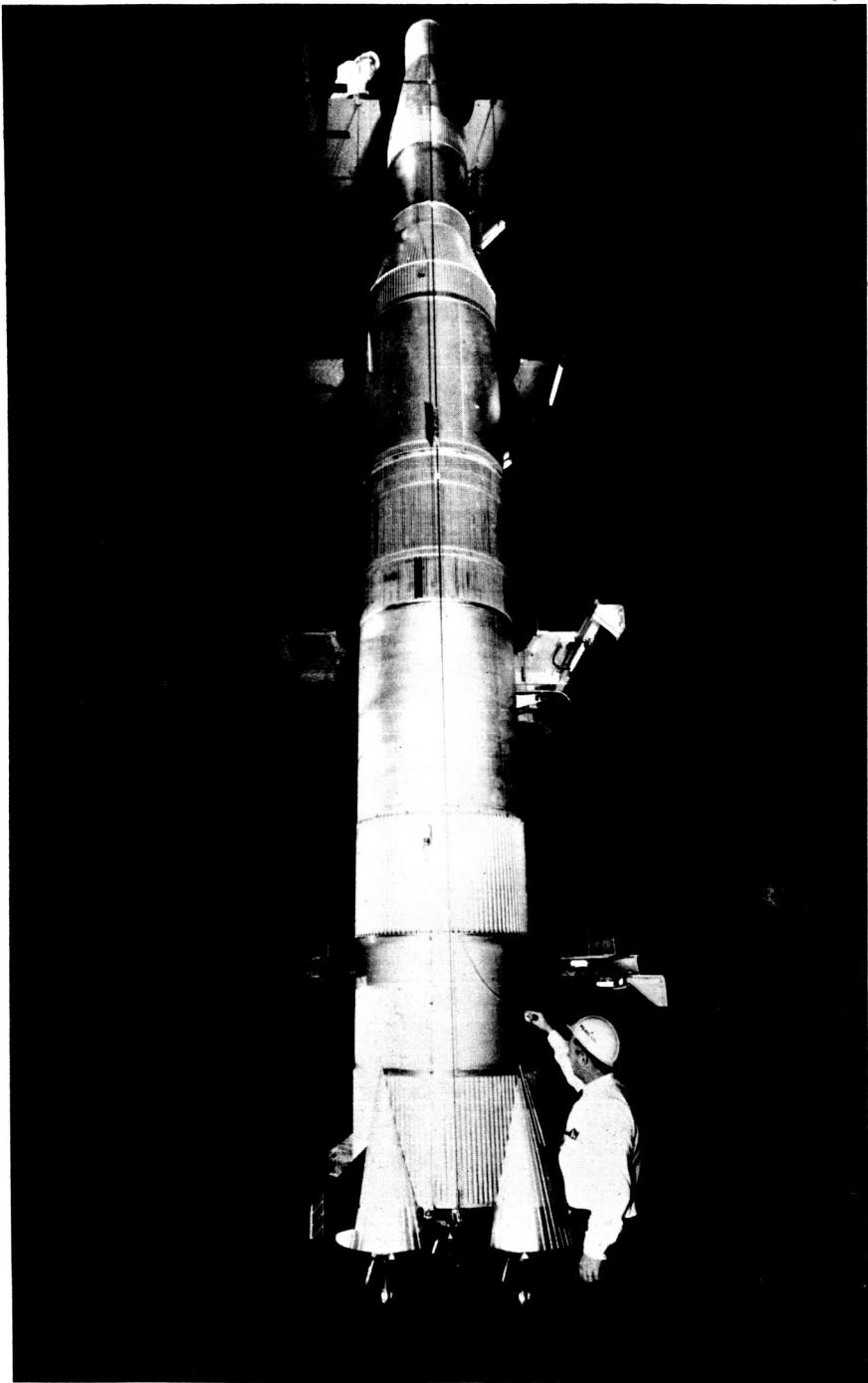
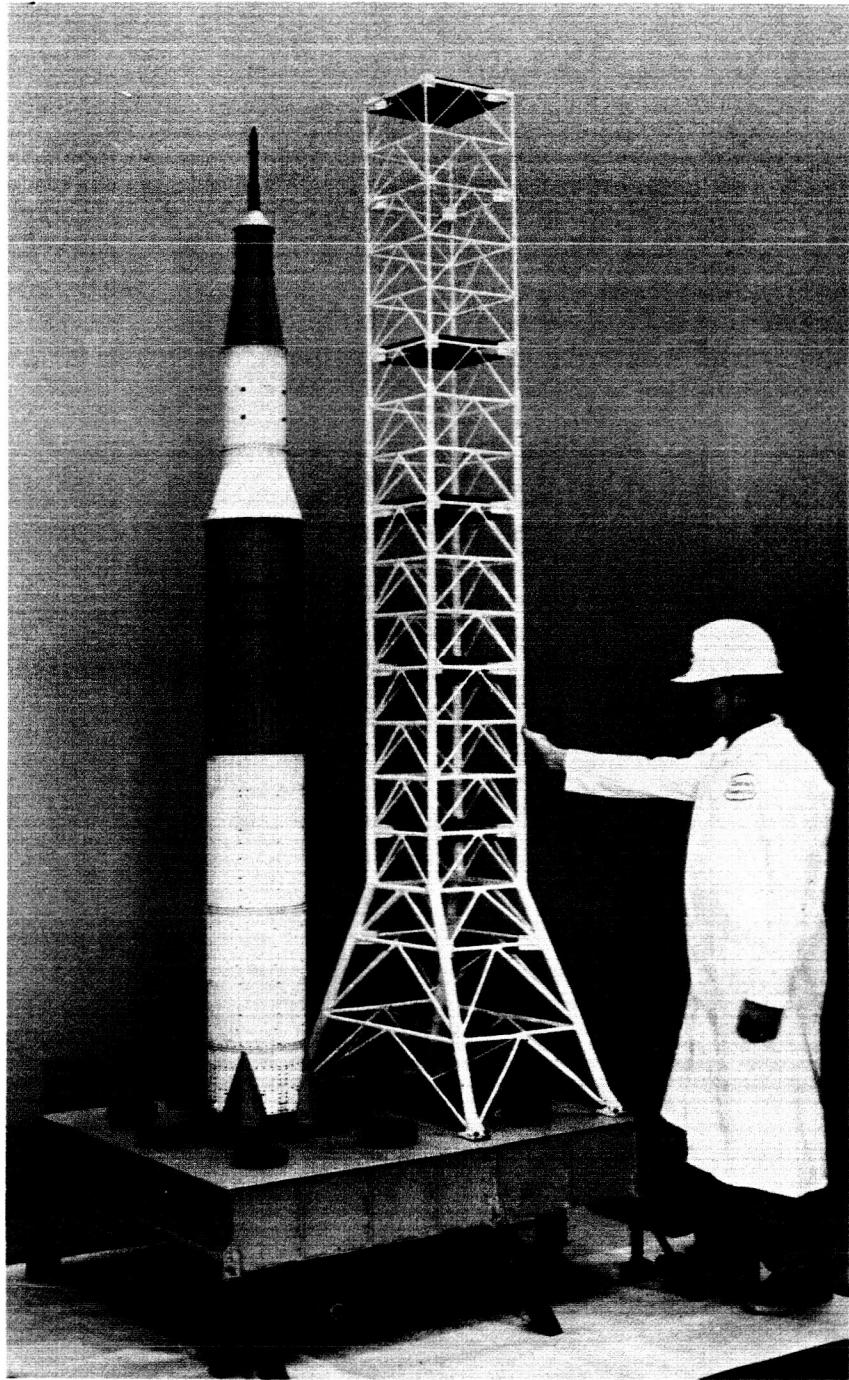


Figure 4-7. Saturn V  $\frac{1}{10}$  (above) and  $\frac{1}{40}$  (p. 97) scale models used for vibration tests.



for developing the technology to economically increase S-band ground antenna apertures significantly beyond the present 210-foot diameter capability.

A 9-foot space deployable antenna (developed for the Jet Propulsion Laboratory) was successfully tested and will be used in laboratory investigations to further refine deployment techniques and ultimately lead to the capability of erecting, in space, antennas as large as 500 feet. A unique multiple-beam phased array antenna developed for GFSC uses an electronically focused and pointed beam which will provide a remotely controlled steerable antenna for unmanned or manned spacecraft. Its use would increase data rates from Mars by as much as 10,000 times over the present capability and make it easier to achieve more varied space research objectives.

#### Instrumentation and Data Processing

The Ames Research Center developed an improved Schlieren optical measuring system which uses an intense monochromatic light source provided by a laser to determine flow characteristics in wind tunnels. Such a laser-Schlieren system reveals the density distribution of a gas as it flows past the test model in a low-density wind tunnel. This system is about 10 times more sensitive than earlier systems. Also, flow details can be identified inside the brilliant plasma surrounding a test model at simulated altitudes higher than 30 miles and speeds greater than 8,000 miles per hour (Mach 10).

The need for such an improvement on the Schlieren optical method (used for many years to obtain data on gaseous flow characteristics in hypersonic wind tunnels) became urgent with the increased use of low-density wind tunnels to simulate high-speed aircraft performance at high altitudes and the consequent difficulty of identifying flow patterns.

Research on strain gages, used to measure force, pressure, acceleration, vibration, and displacements, has made it possible to design silicon strain gages approximately 70 times more sensitive than previous metallic foil units. However, normal silicon units are 28 times more sensitive to temperature variation than the metallic gage. The Langley Research Center was able to reduce the temperature coefficient of some silicon-type strain gages to the same level as that of metallic gages by exposure to controlled doses of electron radiation. The result of this research is a highly sensitive silicon gage with the very desirable small temperature coefficient of the metallic gage.

At the Marshall Space Flight Center, research was conducted on methods of obtaining direct digital measurements in order to eliminate errors introduced by the conversion of analog signals to digital out-

puts. One device being developed uses a photoelastic material to obtain direct digital output from a sensor without mechanical manipulation of parts. This method reduces the error and complexity ordinarily found in analog-to-digital conversion.

### Data Processing

Investigators at Goddard Space Flight Center (GSFC) developed a method of processing data aboard a spacecraft which makes it possible to reduce the volume of data transmitted to earth. In this method, suitable for certain physical measurements such as those made on the IMP spacecraft, the instrumentation counts particles from the directional sensor into 16 groups, each containing the total counts for one-sixteenth of a revolution of the spinning spacecraft. A ground computer can reconstruct a histogram (bar graph) of data with reasonable accuracy if only two factors are transmitted to it: The sum of the lengths of all bars and the sum of the squares of the lengths. These sums can be transmitted using only one-tenth the binary digits required to transmit the number of counts in each of the 16 groups. Thus, this method will reduce the volume of data to be transmitted by about 90 percent. Such a reduction is important since spacecraft can now collect much more data than the communications link can readily transmit to earth.

In other work at GSFC, a data system was developed for use in adjusting a solar simulator employed in testing spacecraft and evaluating radiation damage. It provides a visual display, similar to that of a radar system, of variations in radiation intensity within the simulator vacuum chamber, recording once each second the output of a large number of solar sensors mounted along a rotating arm within the test chamber and exposed to the radiation produced by 127 solar lamps. Equally spaced concentric circles are displayed on the face of a cathode ray tube, each circle representing the path traced by one of the sensors on the rotating arm. Changes in lamp intensity and radiation can be monitored by direct observation of variations in brightness on the face of the tube. This system is a significant advance over previous methods which involved extensive computer manipulation of data and about  $2\frac{1}{2}$  hours of processing.

### Electronic Techniques and Components

Under the direction of the Electronics Research Center, research continued on a thin-film, radiation-resistant device (a thin-film, space-charge-limited triode) with higher tolerance to space radiation than conventional semiconductor devices. The prototype fast scan infrared detection and measuring instrument (*13th Semiannual*

*Report*, p. 94) was in operation and early results indicated that it will exceed its specifications. This device, being developed with Marshall Space Flight Center support, can inspect a square millimeter of circuit in approximately 15 seconds.

## Aeronautics Research

### Aircraft Aerodynamics

Studies were made of the flight characteristics and handling qualities of large sweptwing subsonic jet-transport airplanes in rough-air conditions. Purpose of the studies is to give a better understanding of the airplane handling and recovery procedures necessary during the high angle-of-attack excursions and Mach number overspeed sometimes encountered in rough-air flight. Wind tunnel measurements were made of the dynamic stability characteristics of a model of a typical sweptwing subsonic transport airplane with four wing-mounted jet engines. Results of tests at Mach numbers from 0.2 to 0.94 for angles of attack from  $-6^\circ$  to  $18^\circ$  indicated that this configuration has positive aerodynamic damping in pitch throughout the subsonic Mach number range, except for angles of attack greater than about  $15^\circ$  at Mach 0.2 to 0.6. At these low Mach numbers, the damping decreases rapidly with angles of attack greater than  $8^\circ$ , and becomes negative for angles of attack greater than  $15^\circ$ .

A study was made by analytical and experimental means to determine the drag characteristics over a wide range of Mach and Reynolds numbers for a series of Haack-Adams bodies of revolution which are often used as a basis for obtaining rapid estimates of body wave drag. The models, designed with the use of slender-body theory to have minimum wave drag for a given length, volume, and base area, had fineness ratios of 7, 10, and 13, and were tested at Mach 0.6 to 4.0. Wave-drag coefficients determined by using slender-body theory were in good agreement with the experimentally determined wave-drag coefficients near Mach 1.0, but as Mach number increased, the slender-body theory overestimated the body wave drag. Mach number effects are greater at the lower fineness ratios, and at the higher Mach numbers, the fineness ratio must be very large in order to satisfy the slender-body theory requirements. Computations using the method of characteristics also showed good agreement with the experimental results.

In research on an efficient configuration for hypersonic flight vehicles a theoretical and experimental investigation was conducted to determine the effects of leading edge sweep, thickness ratio, aspect ratio, volume, and Reynolds number on the maximum lift-drag ratio (which is indicative of aerodynamic efficiency) of a variety of rectangular and

delta planform wings at Mach 6.9. The study showed that good predictions of maximum lift-drag ratio can be made for rectangular wings but that the prediction for delta wings is approximately 10 percent high. Other findings included the following:

- For all configurations severe losses of maximum lift-drag ratio occurred with decreasing Reynolds number, and it may therefore be inferred that maximum lift-drag ratio values greater than about three will be difficult to attain at low Reynolds numbers on configurations with useful volume.
- The flat-bottom configuration showed the highest maximum lift-drag ratio on simple shapes where no favorable interference can occur.
- Thickness ratio and aspect ratio, in that order, are prime factors affecting maximum lift-drag ratio irrespective of planform geometry.
- Within a family of shapes, the optimum shape may be determined by use of a composite plot of aspect ratio, thickness ratio, volume-area ratio, and maximum lift-drag ratio.

#### Aircraft Structures

An experimental technique using a scaled model in a large transonic wind tunnel was developed to study the gust response of aircraft. A set of oscillating vanes mounted on the tunnel walls upstream of the test section produces a periodic variation of the angle of the airflow over the model, simulating the response of a full-scale airplane. The simulation is further improved by a previously developed model mounting system employing cables. This combination of cable mounting system, dynamically scaled model, and gust oscillator make it possible to evaluate, at the design stage, the gust response of the actual airplane.

Research continued on the problem of fatigue of aircraft structures. Since fatigue cracks are usually a consequence of the stress concentrations introduced by such things as rivet holes, joints, and notches, research emphasis was placed on the localized material behavior in the vicinity of notches under cyclic loading conditions and on the crack growth characteristics in sheet specimens with stress distributions similar to those in practical riveted sheet-stiffened structures.

#### Air Breathing Propulsion

The major basic research effort in this program was directed toward better understanding the aerothermodynamic flow phenomena associated with hypersonic propulsion systems. Research was conducted on inlet design and placement and on structural concepts capable of withstanding the extreme thermal environment. Much of the research

supports the Hypersonic Ramjet Experiment Project, a specific program to design, develop, build, and flight test to Mach 8.0 an advanced supersonic combustion ramjet engine. Three parallel contract studies indicated the feasibility of the concept and produced considerable information directly applicable to the design and construction of the engine.

### Aircraft Operating Problems

In research on the hazard of compressor or turbine section failures in jet-powered aircraft, NASA undertook a turbine disk-burst study, employing personnel and facilities of the Naval Air Engineering Center, Philadelphia, to determine whether turbomachinery burst protection systems (absorption or deflection) are technically and economically feasible. Data were compiled on uncontained turbine-disk failures to establish the modes of failure and the basis for the theoretical and experimental studies required to evaluate fragment containment and deflection systems. Plans were made for testing current and advanced engine turbine components to provide data on the size, shape, trajectory, and speed of fragments at burst, and the force, energy, and distribution of the fragments on impact.

The modifications to the NASA general purpose airborne simulator system were completed, enabling the Jetstar aircraft to simulate in flight many different types of aircraft. After current flight system checks are completed, the aircraft will be used to study techniques for flying in rough air and to investigate potential flight problems of the supersonic transport.

### X-15 Research Aircraft Program

With all three X-15 aircraft on flight status, 18 flights were made in this period, more than in any other similar period in the program's history. This high flight frequency also led to a total of 32 flights in 1965—the greatest number in a calendar year. The increased activity was accomplished despite repeated cancellations because of bad weather in November and December. Ten of this period's flights were made to altitudes above 200,000 feet. Also, Capt. William J. Knight, USAF, and Mr. William H. Dana, NASA, made their first X-15 flights, joining Lt. Col. Robert A. Rushworth, USAF, John B. McKay, NASA, and Capt. Joe H. Engle, USAF, as X-15 pilots.

On November 3, the X-15-2 made its first flight carrying the two large (37 $\frac{3}{4}$  inches in diameter and 23 $\frac{1}{2}$  feet long) external propellant tanks. (Fig. 4-8.) The tanks were empty for this flight. Airplane handling qualities were good, and tank ejection was accomplished satisfactorily as planned (Mach 2 at 70,000 feet). The anhydrous am-



Figure 4-8. The modified X-15-2 with external fuel tanks.

monia tank was recovered satisfactorily, but the parachute recovery system for the liquid oxygen tank failed, and the tank was destroyed on ground impact. The next flight with the empty external tanks was scheduled for the first half of 1966, and flights were planned for later in the year with the tanks filled (13,500 pounds of propellant). Flight envelope expansion—from Mach 6 to approximately 8—will then proceed in orderly steps.

Modification of the X-15-3 for the boost-reentry guidance and the energy management experiments was begun in November. Modifications include replacement of the present analog system with digital

inertial flight data system—similar to that used in the X-15-1 since October 1964.

The Fourth Air Force-Navy-NASA Research Airplane Committee Conference on the progress of the X-15 Research Airplane program held on October 7, at Edwards Air Force Base, Calif., was attended by approximately 500 representatives from industry and Government. Topics discussed included current status and future plans, development of the X-15-2 aircraft and thermal protection system, heat-transfer, skin friction, boundary-layer noise, controllability, reentry research, results of several scientific test-bed experiments, and planned hypersonic propulsion system testing.

The aircraft were used for the following investigations during the last half of 1965:

*The X-15-1.*—Massachusetts Institute of Technology horizon definition experiment, basic X-15 stability and control evaluation, infrared scanning radiometer experiment, high-altitude atmospheric density measurements, ablation materials evaluation (required for Mach 8 configuration flights), checkout of additional X-15 project pilots.

*The X-15-2.*—Stellar ultraviolet photography experiment, handling qualities evaluation with external tanks, tank separation characteristics, tank trajectory following in-flight jettison, evaluation of Mach 8 configuration landing dynamics, functional check of reaction control augmentation system modification.

*The X-15-3.*—Aerodynamic boundary-layer noise measurements, horizontal stabilizer loads investigation, Langley Research Center horizon scanner experiment, reentry maneuver techniques, rocket engine ultraviolet exhaust-plume characteristics measurements, earth-background-radiation measurements, additional X-15 project pilot checkout.

At the end of 1965 the 3 X-15 airplanes had been flown 156 times, including 117 flights at speeds of Mach 4 and above. Maximum velocity and altitude were 4,104 m.p.h. and 354,200 feet.

### **Supersonic Transport**

In a cooperative FAA, USAF, NASA program to measure the radiation environment of the supersonic transport, NASA is undertaking to map the particle flux of biologically important components of radiation such as protons, neutrons, heavy primaries, and bremsstrahlung. Instrumented balloons were sent to altitudes of about 100,000 feet to obtain data on radiation intensity variation with altitude in the air and in tissue-equivalent instrumented material simulating a part of the human body. Special neutron and proton sensors were being developed for installation in aircraft to measure the radiation over a

range of latitudes and longitudes and during various portions of the solar sunspot cycle. In one test, radiation measurements were made at jet transport altitudes on an around-the-world flightpath that crossed both poles.

Investigators working on the design of supersonic aircraft have done considerable research on the variable sweep wing. One concept studied involved a fixed outboard pivot and a fixed, highly swept, in-board wing section designed to minimize aerodynamic center shift. Results of small-scale tests gave evidence of longitudinal instability characteristics at the stall for the high-lift configurations of this design. Low-speed tests were made on a basic, large-scale, low-wing, variable-sweep model to investigate the longitudinal instability. The tests were limited to the first-order effects of the most important variables: wing sweep in low-speed cruise and high-lift configurations, wing aspect ratio, trailing-edge flap systems, leading-edge slots, horizontal-tail area and location, and fixed-wing leading-edge radius and flaps. All configurations tested, except one, were longitudinally unstable at high lift. The one configuration that essentially eliminated instability at stall consisted of a drooped fixed-wing leading-edge with a high-aspect ratio wing at 25° sweepback, in conjunction with a low horizontal-tail position. The longitudinal instability could not be eliminated with the horizontal tail in any other than the low position. Placing the tail at a high position caused a severe pitchup. In a mid-position it was somewhat better, but the longitudinal characteristics were still unsatisfactory. Reducing wing sweepback below 25° yielded no appreciable benefit in terms of a maximum-lift coefficient or the lift coefficient at which pitchup occurs.

#### Vertical and Short Takeoff and Landing (V/STOL) Aircraft

The downwash from VTOL aircraft can produce problems of surface deterioration when the high velocity, high-temperature exhaust gases impinge on unprotected natural surfaces. Efforts to overcome such problems have included development of operational techniques which reduce exposure of the surfaces to the downwash and research on ways of rapidly preparing the sites with surface coatings. In addition, NASA sponsored a program to evaluate various exhaust nozzle design factors which could lead to a reduction of dynamic pressures and temperatures at the ground surface. In a follow-on program, the jet wake degradation and thrust characteristics of 11 exhaust nozzle models designed for dynamic pressure and temperature reduction in the jet were evaluated statically, using both hot gases and unheated air, and similar tests were conducted with a reference circular nozzle. Additional tests of selected nozzles were conducted to deter-

mine effects of fuselage and/or proximity of a ground plane on thrust and jet wake characteristics. Significant jet wake degradation resulted for all suppressor nozzles tested, both in and out of ground effect and with various fuselage configurations. Jet wake degradation was most rapid with nozzle designs having widely spaced and/or high-aspect ratio nozzle elements. Thrust losses were minimized in nozzles having small exit wall divergence angles and moderate values of aspect ratio of the discharge openings. Combining the nozzles with a fuselage resulted in additional thrust losses, which increased further during operation near a ground surface. Ventilation of the fuselage reduced thrust losses, particularly with suppressor nozzles, but all nozzle and fuselage configurations exhibited large losses when tested in proximity to a ground surface. The thrust losses were associated with the large projected fuselage area used in the tests, and it was concluded that the projected area must be minimized to avoid excessive losses during operation in ground effect.

In high-performance STOL aircraft, power changes sometimes produce undesirable trim and stability changes. A study was made of the effects on pilot opinion of trim change with power. Using a moving cab simulator which included a visual runway presentation, the landing approach and waveoff of a high-performance deflected-slipstream aircraft were simulated. Various changes of pitching moments with power were investigated at several levels of static longitudinal stability, and a configuration that tended to pitchup and one that showed a reduction of static stability with increasing power were studied. At the more positive levels of static longitudinal stability, the lift produced by power markedly affected the apparent pitching moment due to power. In general, the study determined that pilots preferred configurations which exhibited the least trim change with power or those for which the power effects did not aggravate the stall or pitchup margin.

A STOL seaplane was developed by the Japanese Maritime Self Defense Force as a test bed to investigate the potential of a seaplane with low landing and takeoff speeds. The aircraft, the UF-XS (fig. 4-9) utilizes Boundary-Layer Control (BLC) and the propeller slipstream to fly at low speeds, Automatic Stability Equipment (ASE) for improved handling at low speeds, and a hull with good hydrodynamic characteristics. Preliminary Japanese flight tests indicated that these features allowed the aircraft to operate in seas with 6-foot high waves.

In additional work on the Japanese STOL seaplane requested by the U.S. Navy, a simulator study of the handling qualities in the STOL regime was made at Ames Research Center to obtain a pre-

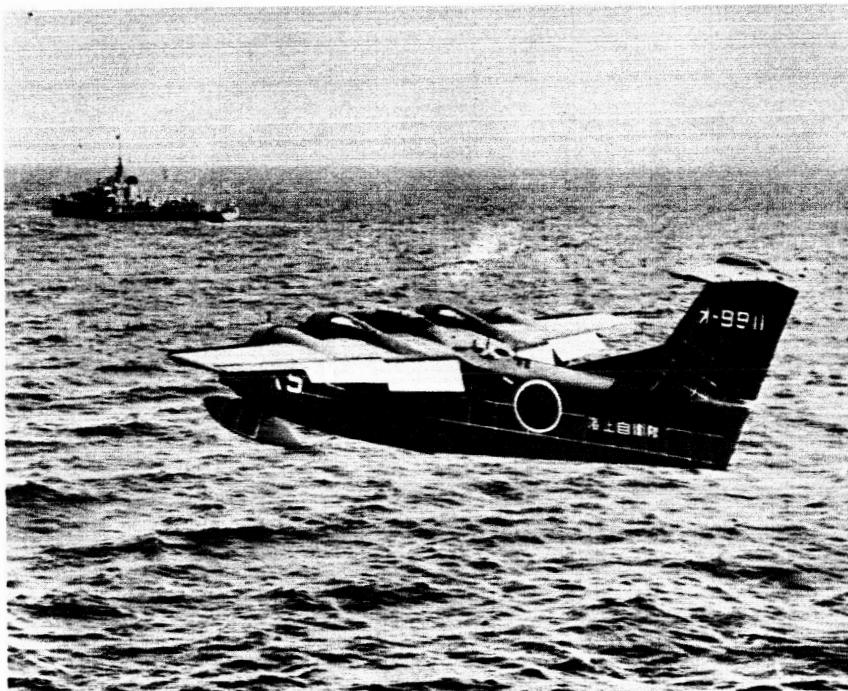


Figure 4-9. The Japanese UF-XS STOL seaplane.

liminary evaluation, to study potential problem areas and their solutions, and to investigate areas beyond the normal flight envelope of the UF-XS. Next, NASA and the U.S. Navy conducted flight tests, during which takeoffs and landings were made from water at 50 knots, corresponding to a lift coefficient of about 4. With the ASE engaged, the handling characteristics of the aircraft were satisfactory. The ASE provided roll and pitch attitude stabilization and increased rate damping about these axes. With the ASE off, the handling characteristics were unsatisfactory because of low static longitudinal stability, a very unstable spiral mode, and large sideslip excursions during turn entries. Response to control inputs was satisfactory about the roll and pitch axes, but the like-rotation propellers reduced the directional control to an unsatisfactory level.

Wind tunnel studies were continued on the Triservice X-22 four-duct tandem V/STOL airplane. (Fig. 4-10). These investigations included free-flight model studies in the Langley full-scale tunnel and static tests in the 17-foot test section of the 300 m.p.h. 7- by 10-foot tunnel to investigate stability and control characteristics in transition, takeoff, and landing.

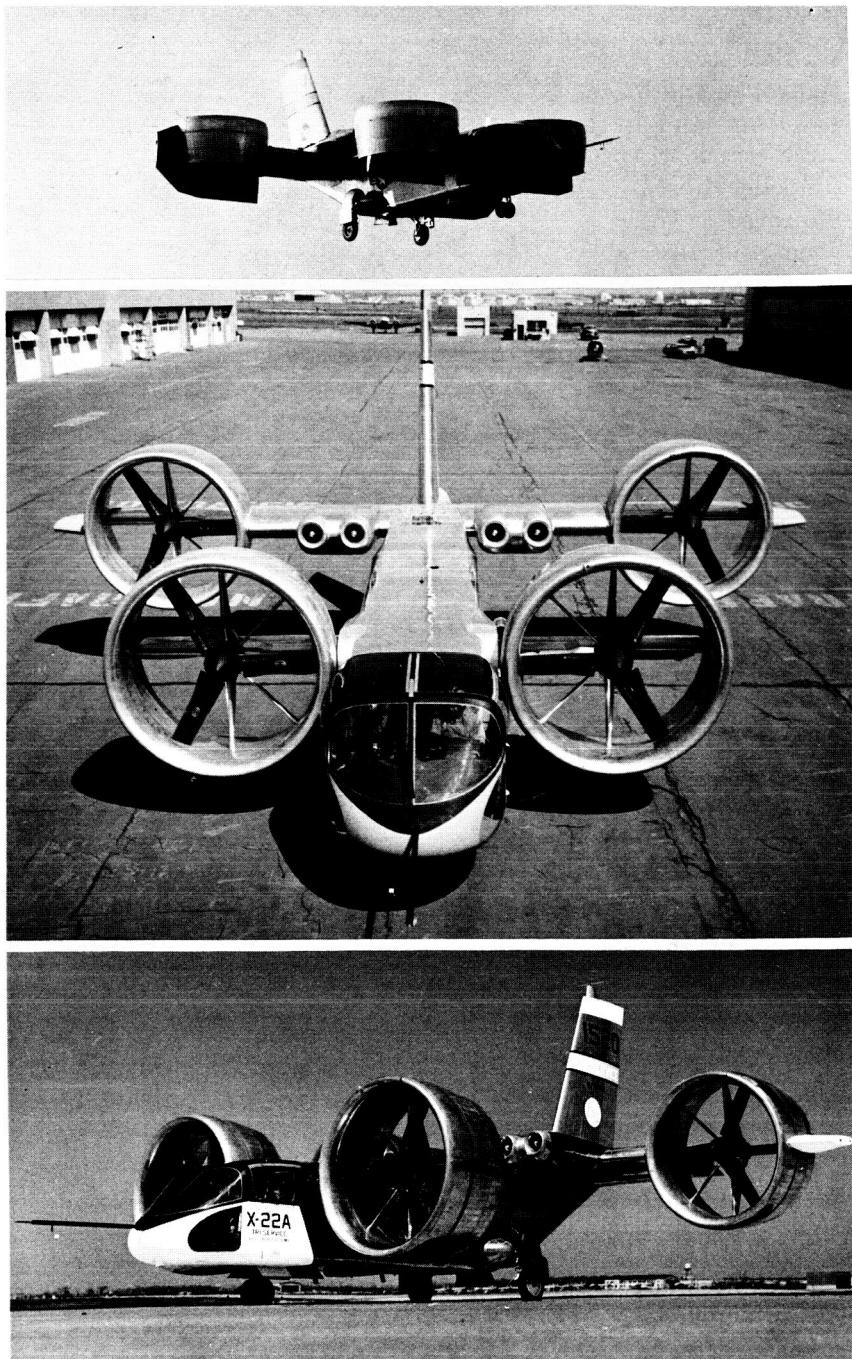


Figure 4-10. The Triservice X-22 V/STOL Aircraft.

In the free-flight tests, the model had unstable pitching and rolling oscillations in hovering flight out of ground effect, but it could be controlled and maneuvered easily since the period of the oscillations was long. In hovering flight near the ground, the model experienced large erratic disturbances caused by the recirculation of the ducted-propeller slipstream. In the transition range the longitudinal stability improved as speed was increased, and the pitching oscillations were about neutrally stable at the high speed end of the range. Throughout most of the transition speed range, the model had very low directional stability and an unstable directional-lateral oscillation (Dutch roll), which could be alleviated by using artificial damping in yaw. Also stalling of the upper outside duct surfaces caused large erratic rolling moments or wing dropping in the landing-approach condition. In all flight regions, the minimum total control powers found to be satisfactory in the model flight tests were approximately equal to or less than the control powers planned for the full-scale airplane.

The static stability tests indicated that the original configuration was longitudinally unstable at high thrust coefficients in the cruise condition. Longitudinal stability was achieved by reducing the size of the front fairings between the ducts and the fuselage thereby diminishing the destabilizing effects of the ducts. It was found that trim and control requirements in the transition-speed range could best be attained by a combination of differential thrust and deflection of vanes within the ducts.

The Ames Research Center investigated a method of driving and controlling a helicopter rotor by a variably deflectable jet flap. The theoretical study, based primarily on the results of high-speed digital computations, indicated that higher speeds could be attained in pure helicopter flight with this jet-flap rotor concept than with any conventional rotor. The results of the study indicated that it would be worthwhile to evaluate the concept experimentally, and a joint program with the Army was established.

This design offers potential advantages of mechanical simplification, increased lift and propulsive force, and reduced vibrations. It may be applicable to three types of pure helicopter: a high-speed (over 200 knots) low-drag vehicle, an efficient medium-speed vehicle, and a crane helicopter.

#### **XB-70 SST Flight Research Program**

Acquisition of research data from this program began with the first XB-70 flight in 1964 (NASA, *13th Semiannual Report*, p. 105), and was accelerated during this period as the second aircraft made its first flight (July 17). During the initial phase of the NASA XB-70 program critical problem areas related to the national supersonic trans-

port program were investigated. To provide for increased use of the XB-70 in support of the NASA SST research program, NASA and the Department of Defense signed a memorandum of understanding on May 28, 1965, recognizing the importance of the NASA portion of the XB-70 program. A management agreement, implementing the memorandum of understanding, was signed by the Air Force and NASA on October 11. Full NASA participation in the XB-70 program is expected to begin in June 1966. (Fig. 4-11.)

Major emphasis during the first 23 flights of the XB-70 was on evaluating stability, control, and handling qualities, demonstrating structural integrity, testing engine inlet and environment control systems, and expanding the flight Mach number and altitude envelope.

Since the size, weight, and speed characteristics of the XB-70 are similar to those of proposed SST designs, measurements of the XB-70 sonic-boom pressure signatures were obtained in flight under conditions comparable to those predicted for the SST. This data, for use in improving present sonic-boom theoretical calculations, indicated that the near-field pressure signature of the XB-70 extends to a greater distance than had been anticipated. Also, the XB-70 near-field pressure signature was compared with the B-58 far-field pressure signatures. The maximum overpressure of the XB-70 was found to be only slightly greater than the B-58 bow-wave overpressure, although the weight of the XB-70 was approximately 3.5 times that of the B-58. In the tests, both airplanes were at the same altitude and Mach number, and the B-58 was about 800 feet behind the XB-70. A reduction in near-field bow-wave pressure in the proposed SST (about the same size and weight as the XB-70) would favorably affect its design and operation, allowing higher speed at lower altitudes and compliance with maximum design overpressure requirements.

The XB-70 sonic boom data were obtained at speeds ranging from Mach 1.2 to 2.6, and at altitudes from 27,000 to 64,000 feet. Much additional data will be required to assess the effect of Mach number, altitude, gross weight, and weather, but results of the limited data collected to date were quite encouraging.

## Biotechnology and Human Research

### Biotechnology

*Life Support and Protective Systems.*—In work on equipment for environmental and atmosphere control, studies were made of methods and techniques for controlling the origin of toxic contaminants, research was conducted on components and subsystems which can be used for the containment and conversion of toxins to nontoxic materials, standards were established for allowable concentrations of

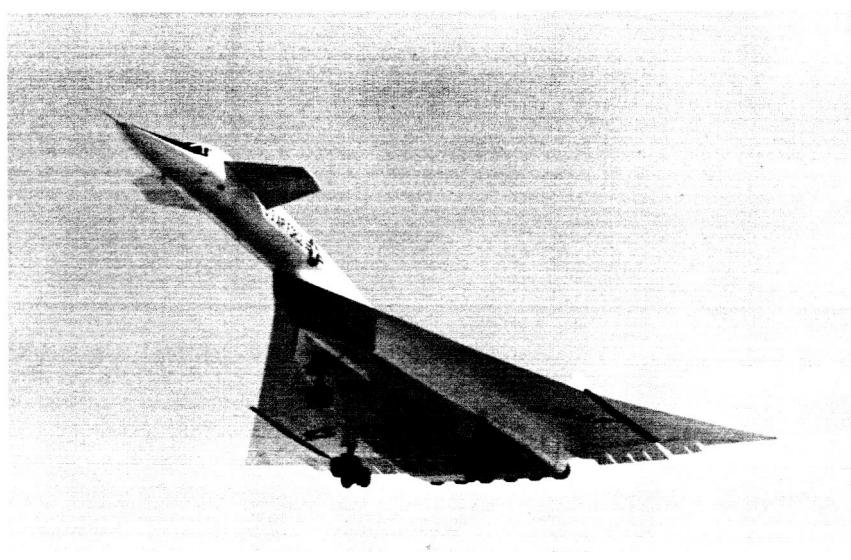
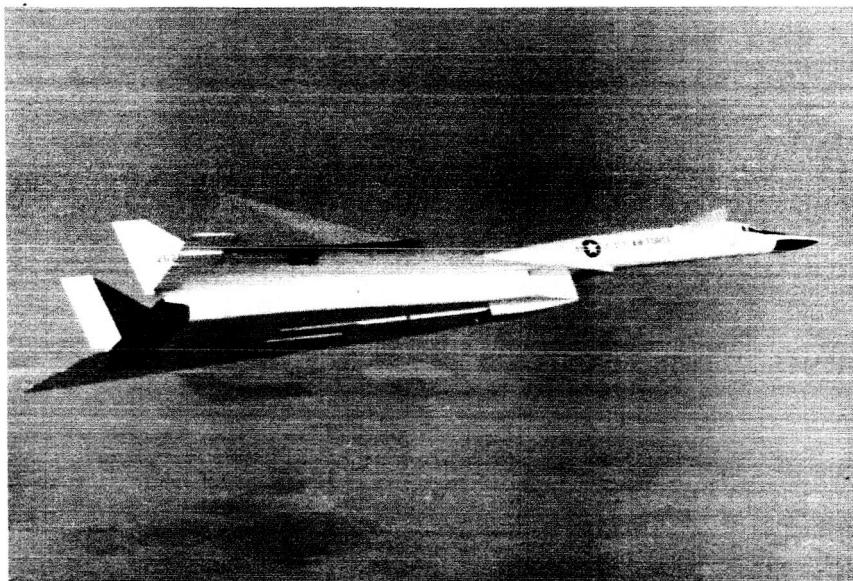


Figure 4-11. The XB-70 in flight.

toxic materials in atmospheres over extended periods of time, and methods were developed for detecting toxins in a predetermined range.

Research was conducted on methods of preventing atmospheric contamination by toxic substances in low-leakage-rate sealed cabins for long duration space or undersea operations.

One study was concerned with toxic materials used in spacecraft structures and chemical processing equipment. Another investigated the effect of normal atmospheric components, such as oxygen and nitrogen, on spacecraft materials at various temperatures and also the action of metabolic products on spacecraft atmospheric purification equipment and chemicals. In addition, the generation of toxic materials from normally nontoxic reactants and from the interaction of the products of physical, chemical, and biological waste conversion and reclamation systems was studied.

Physical-chemical and biological techniques were being developed for life-support systems to recycle man's waste products and reuse these products for his food, water, and oxygen requirements. Concepts for new methods of food storage, packaging, and preparation were studied, and cooked, freeze dried foods were packaged and stored for considerable periods of time without deterioration. More advanced concepts under consideration included liquid diets and completely closed ecological cycles. Atmosphere systems which provide oxygen from chemicals were developed. Considerable work was done on the analysis of radiators, used to dispose of waste heat in space, and on the thermal balance of vehicles. This research is potentially applicable to the development of technology for industrial, commercial, or public uses in such areas as atmospheric pollution, water purification, and waste processing techniques.

### **Human Research**

*Body Systems.*—In life science research, baseline data were being collected on the pigtailed monkey which is used extensively in this field, and new simplified methods were being developed for the measurement of body density. Also, the first practical machine to measure cerebral circulation—a lightweight portable device called the Rheoencephalogram—and a simple "pocket-sized" recording EEG machine were developed.

*Environmental Physiology.*—In research on the vestibular system and motion sickness, a paper and pencil test was developed which will predict the degree of motion sickness a person is likely to suffer. The same program also produced the first known means of reliably establishing the degree of impairment present in the inner ear or vestibular system and a reliable technique for measuring the effectiveness of drugs to prevent motion sickness.

*Bioinstrumentation.*—Research in this area included studies of the requirements for implanted instrumentation and tests of sensors as well as further work on previously developed devices. (*11th Semianual Report*, p. 112.) Also, a program was conducted for develop-

ment and qualitative analysis of a myocardiographic sensor as a means of evaluating vibrocardiographic data. Post-implant recordings, including left ventricular pressure and electrocardiograms, were taken over a 30-day period. Finally, a spray-on technique was developed for rapid and secure application of electrodes for sensing EKG and other biopotentials. About 30 seconds are required for the application of each electrode which may then remain in place for several hours with little or no discomfort to the wearer. Shaving of the electrode area is unnecessary.

### **Man-Systems Integration**

*Manual Control System.*—Studies were underway to determine how pilots perform under adverse aircraft flight conditions and to better quantify pilot performance under normal and unusual flight conditions. Computer analogs of the pilot are used to determine how the pilot controls a high performance aircraft during normal flight. He then flies the simulated plane under varying flight dynamics conditions. His performance is analyzed to determine changes in control behavior in response to stress and to indicate required levels of stability augmentation. These studies are expected to lead to design criteria for improved display and control systems for private and commercial aircraft.

*Behavioral and Psychomotor Testing.*—Cognitive and psychomotor tests and test batteries were also studied. Such tests, which can be used to predict performance and to measure human abilities, may also be used to test applicants for vocational training and for industrial jobs requiring manual dexterity. They can also be used as a basis for identifying special skill requirements for manual jobs to improve job engineering studies.

*Human Decision Making.*—Investigations were being carried on to determine the effects of various types of signals on human responses. Information on how the human brain processes data would enlarge our understanding of man's intellectual functions and be useful for the design of computers and display systems.

*Automatic Vision Testing.*—A visual acuity and visual performance measurement device was under development. It will provide quantitative information on acuity, brightness threshold, depth perception, and color perception. Easy to operate and applicable to group testing, it may be used for screening large groups in some of the critical visual skills.

*Quality Control.*—Efforts were underway to identify the causes of human failure in the fabrication and assembly of equipment for unmanned space vehicles. Findings from this study will be valuable

to industry as well as to NASA since commercial products are also affected by human errors in the manufacturing process.

*Prevention of Cardiovascular Deconditioning.*—Also under study were methods to eliminate or reduce deconditioning of the cardiovascular system resulting from bed rest. Astronauts on extended trips could be subject to such deconditioning, and medical patients confined to beds for long periods of time frequently suffer from inability of the heart-blood vessel system to sustain normal activity when the patient arises from the bed. Consequently, this research can provide useful data not only for space researchers but also for the medical profession on ways of eliminating or alleviating this problem.

## Chemical Propulsion Systems

### Solid Propulsion Research and Technology

Langley Research Center has developed outstanding competence in simulated dynamic testing of solid rocket motors. Using a centrifuge and spin apparatus, the Center collected data from systematic studies of the effects of dynamic loading on solid rocket performance and made it available for application to the design of future motors. Both Langley and the Jet Propulsion Laboratory engaged in solid-propellant combustion research in order to accumulate technical data and develop theory to assess the burning rate characteristics of new propellant compositions before their preparation. In addition, information from this research can be used to analyze transient combustion conditions during termination, ignition, instability, and transition from deflagration to detonation.

The Jet Propulsion Laboratory has conducted extensive research on propellant structural integrity and related problems. This research produced a number of failure criteria theories and valuable equipment to measure stresses and propellant mechanical properties. In addition, the structural integrity program acquired data applicable to the behavior of the whole range of viscoelastic materials, and thus also useful in the plastic and rubber industries as the basis for stronger, oxidation- and abrasion-resistant, and modifiable materials.

Research also continued on the requirements for command stop-restart and thrust variation in solid propellant motors, on technology problems in the use of hybrid propellant systems, and on the kinetics of decomposition, chemical erosivity, instability characteristics, physical properties, sensitivity, and processing characteristics of high performance propellants.

A program to detect flaw growth in steel rocket motor cases was underway. Designed to establish the technology and develop the equip-

ment to monitor hydrotests and prevent catastrophic failures, the program is directly related to the cost of very large rocket motor cases, the long fabrication time, and the requirement for highest reliability. The detection method is based on a network of small accelerometers placed on the steel case, which detect small shock waves in the steel produced by microscopic flaws as they enlarge. By timing the arrival of the shock waves at three or more points, the origin of the shock wave and hence the location of a flaw can be computed. The hydrotest can be stopped and the flaw repaired. In final form, the system would consist of the accelerometers, recorders, a computer to provide instant information on flaw locations, and a mechanical valve system to reduce the hydrotest pressure in time to prevent catastrophic failure.

#### **Large Solid Propellant Motor Program**

The large solid rocket program deals with a class of solid rocket motors capable of producing 3 to  $7\frac{1}{2}$  million pounds of thrust, 260 inches in diameter, and 80 to 150 feet long.

The first 260-inch motor was loaded with 1,680,000 pounds of propellant early in June. (Fig. 4-12.) The subsequent operations of curing the propellant, removing the casting mandrel, attaching the nozzle, and placing the igniter proceeded without difficulty. The motor was fired on September 25 with complete success. The thrust level reached a peak of  $3\frac{1}{2}$  million pounds during the 125 second firing. This was the largest single rocket motor ever fired in this country. Postfiring inspection showed that all major components and materials had performed satisfactorily. (Fig. 4-13.)

The steel chamber for the second motor passed its hydrotest on August 14 at a contractor facility, and was shipped to the loading plant in Florida. The motor case was then insulated internally with sheets and sections of rubber and prepared for propellant casting. From November 29 to December 9, 1,695,000 pounds of propellant were produced and cast in the case, and the motor was held at a temperature of  $135^{\circ}$  F. through December to cure the propellant.

Plans for the large motor program after the firing of the second motor (scheduled for late February 1966) were under detailed study. The ultimate objective of the program is the demonstration of a prototype 260-inch motor containing a vector control system and a failure warning system, with the thrust time best suited to the requirements of potential launch vehicles; the immediate objective is to develop these features with subscale motors.

A supporting study made by a contractor to define the characteristics of the final motor showed that the 260-inch class of solid motor can be used with the S-IVB Stage of the uprated Saturn I to place

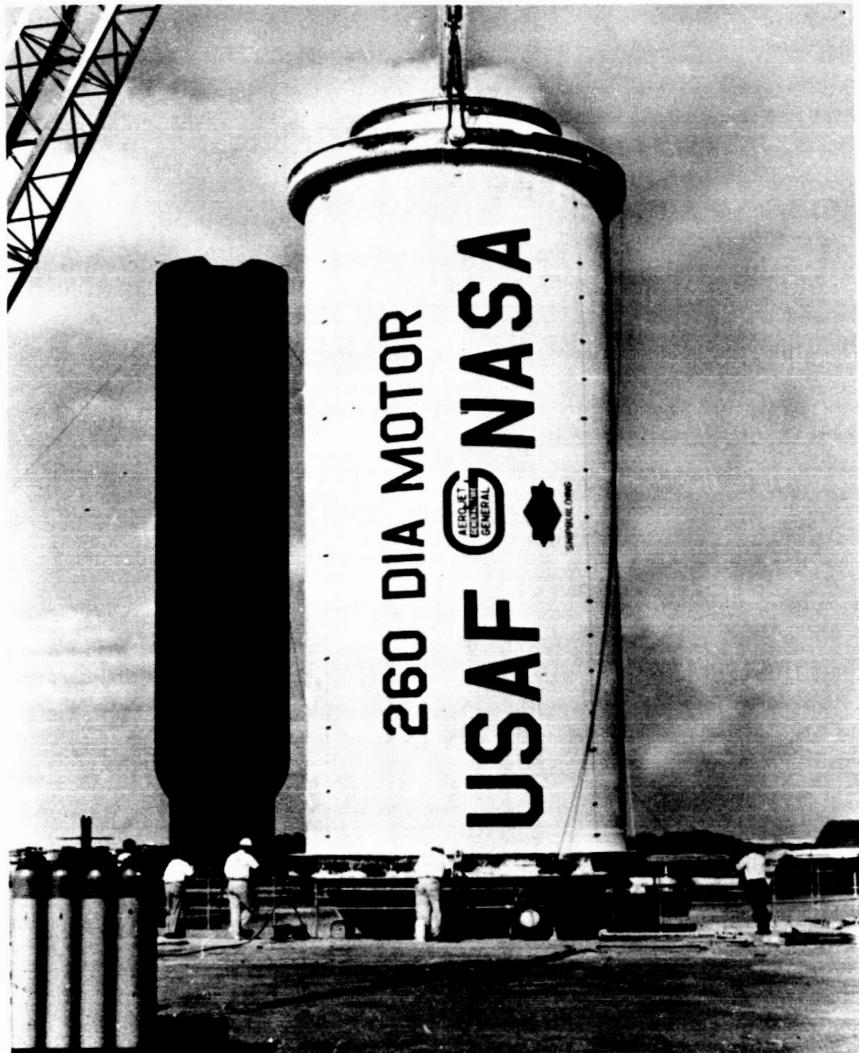


Figure 4-12. 260-inch motor case being lowered into firing pit before loading with propellant. Casting mandrel to left of casing.

payloads up to 90,000 pounds in earth orbit. The estimated operational cost effectiveness of this launch vehicle is excellent: \$225 per pound in earth orbit. Other studies showed that the 260-inch diameter motor in various combinations with NASA vehicles and stages can provide a launch vehicle capability extending to 750,000 pounds in earth orbit and can also provide important booster elements for future larger launch vehicles.

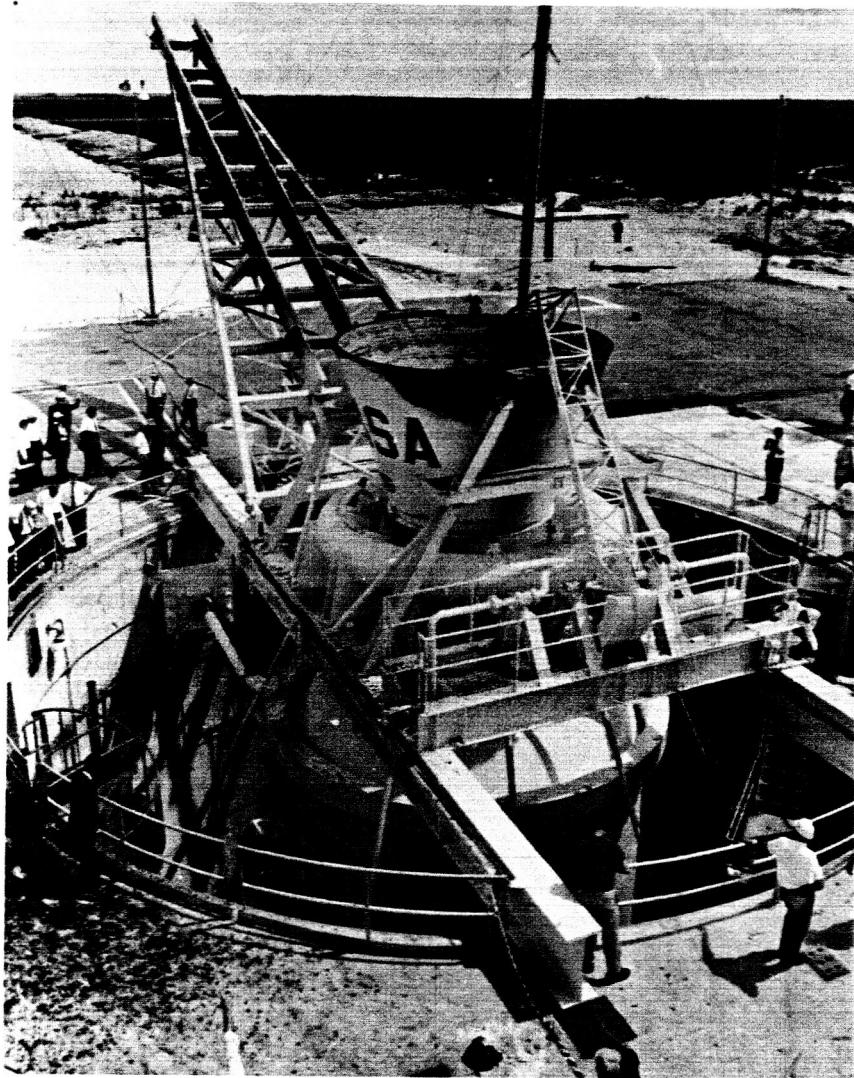


Figure 4-13. The 260-inch motor after firing.

#### Liquid Propulsion

*Launch Vehicle Propulsion.*—In this program, work continued on the toroidal motor concept (fig. 4-14) with studies of high pressure and film cooling, the relationship between throat and nozzle entrance contouring, and of cycle design. Thrust vector control requirements for large vehicles were also identified.

In connection with the toroidal combustion chamber research, the Lewis Research Center began an extensive analysis of various nozzle

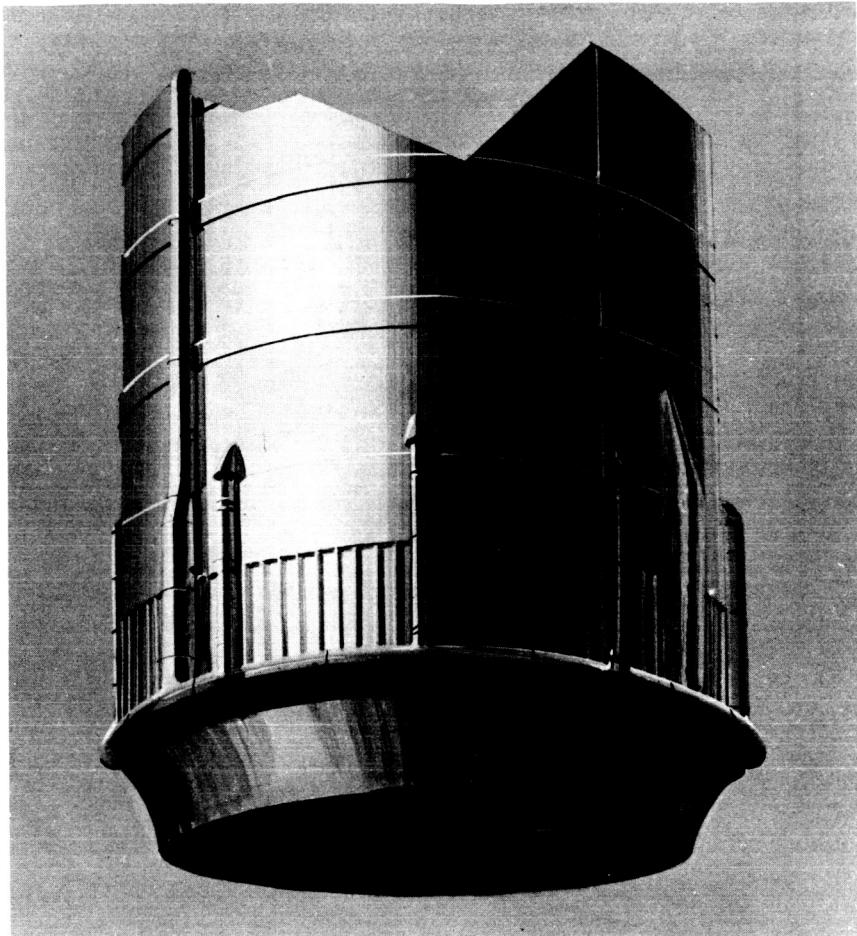


Figure 4-14. Toroidal engine installation.

systems including the aerospike concept. In the toroidal engine, the combustion chamber is a tube wrapped laterally around the base of the vehicle. The tube ejects the exhaust gases against the plug nozzle, thus increasing the total expansion ratio and thrust delivered to the vehicle. Nozzle configuration studies showed that the introduction of secondary gas into the plug nozzle improves its thrust coefficient and that the areospike nozzle was superior to the bell nozzle. (Fig. 4-15.)

The composite cycle study (*13th Semiannual Report*, p. 111) made good progress. Thirty-six engines using air in some form were analyzed for launch vehicle performance over three trajectories. Fourteen engines showed sufficient potential to justify investigation in

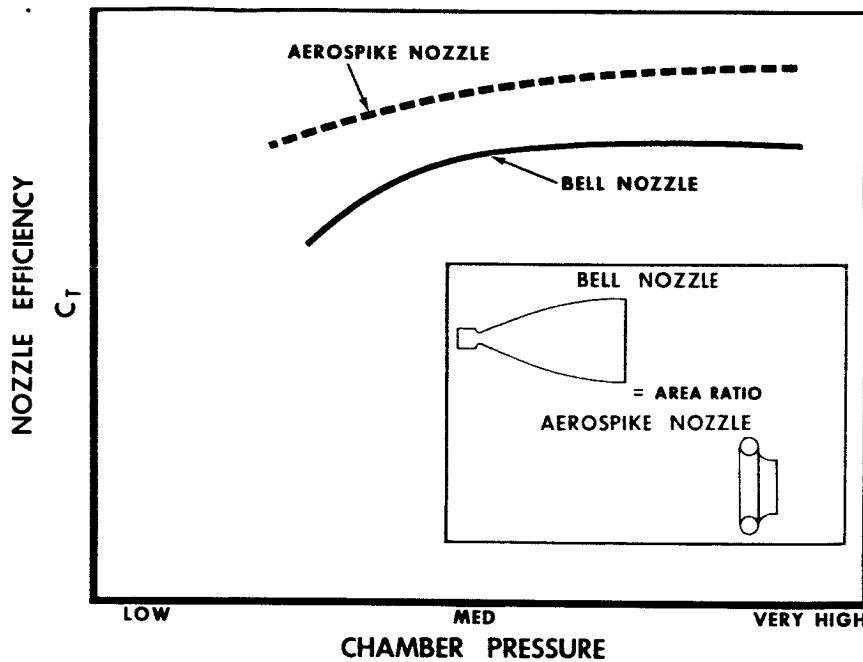


Figure 4-15. Comparative nozzle efficiency.

greater depth. The ultimate aim of this effort is to analyze subsystems to identify critical and pacing technology requirements for an air-using launch vehicle engine which may later be the basis for development of a recoverable booster.

*Spacecraft Propulsion.*—Research effort in this area is directed toward developing relatively new concepts to the degree of high reliability that will permit them to be applied with confidence to long-term space missions. The prevention of leakage is a key requirement, for what is ordinarily a low leakage rate can be a disastrous rate on long-term missions. Methods of detecting leakage and of reducing the leak rate for reusable and/or restartable systems were investigated. Attention was focused on "wet" liquid metal seals, radiation heating of valves, Joule-Thompson expansion for refrigeration in vent systems, and thin film technology. A leak detection device, simple in concept, accurate, and portable, was developed and put in use checking shutoff valves. (Fig. 4-16.) Also, a leakage detection manual was being prepared. Another problem area is related to the fact that space storable propellants burn hot and cool poorly. Work on high-temperature materials for combustion chamber construction and on design criteria to minimize the heating effects during combustion, included studies of ablative systems, refractory materials, oxidizer resistant

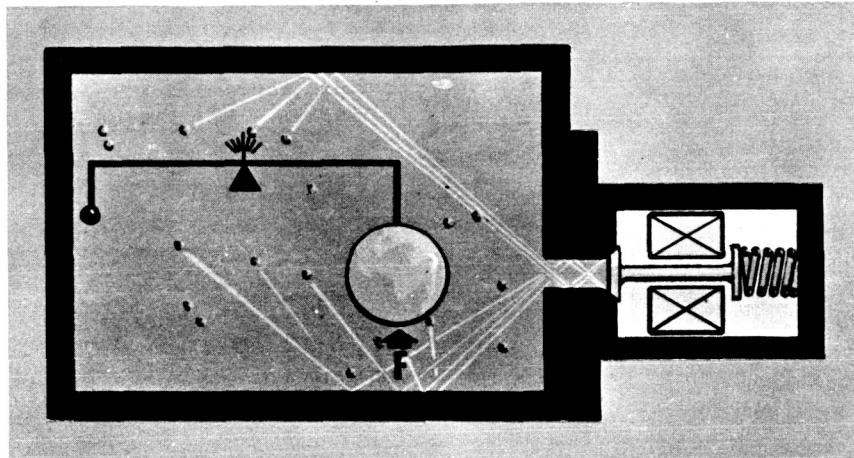


Figure 4-16. The leak detection device.

coating, and heat transfer. Other research was conducted on methods of achieving the positive control of fluid location required by the zero-gravity environment. Bladders can provide this control if they can last for a sufficient length of time. Efforts to determine the applicability of bladders included investigations of various special rubber and polymer materials, mechanical performance during use, flexing with reusability, and design criteria.

*Propellants.*—Liquid hydrogen is suitable for both launch vehicle and spacecraft propulsion applications. Slush hydrogen, a dense slush state, was investigated as a means of making hydrogen more space storable. The slush offers the advantages of a less frequent venting cycle and smaller volume for weight, making possible as much as a 15-percent volume reduction. Work in the gelled hydrogen program stressed production of very small particles for the gellant material and production and storage of sufficient quantities for batch usage.

*General Research.*—This work on combustion stability theory and hydrodynamic analysis of flowing systems (including heat exchangers, inducers, pumps, and ducts) was carried on primarily at universities.

As the M-1 program approached its 1966 termination date, major emphasis was placed on demonstrating full-scale components. The gas generator was integrated with the oxidizer turbopump and tests were conducted during August and September. Testing of the liquid hydrogen pump using the gas generator as a power source was completed in December. The test showed the capability of the pump to handle over 50,000 gallons of liquid hydrogen per minute, several times greater than any previous hydrogen pump. With the completion of turbopump testing in December, that portion of the M-1 pro-

gram was deactivated. The remaining large component, the injector, is scheduled to be tested in an uncooled thrust chamber to establish combustion stability and scaling relations for the largest liquid oxygen—liquid hydrogen combustion device ever built. These tests will run through the summer of 1966 at which time final termination of the program will take place.

The termination of the M-1 program leaves NASA without a candidate engine for future advanced launch vehicles, although more advanced concepts for launch vehicle engines have been under investigation for several years. Two such advanced engines were being seriously considered:

- The high-pressure, dual-combustion-cycle engine, and
- The toroidal chamber-plug nozzle engine.

Work was continued on a design study of the high-pressure concept and demonstration of a model-scale high-pressure hydrogen pump. Work was also initiated on a companion liquid oxygen pump, and plans were made for a design study and an engine dynamics program on the toroidal concept. NASA coordinated its work on the advanced concepts with the Air Force, and a joint plan for investigation of the design and hardware problem areas was evolved. Complementary work being carried on by both agencies will culminate in two model-scale breadboard system demonstrations in 1967 to determine the relative merits of the two concepts.

Space propulsion research continued to emphasize the application of high-energy propellants to upper stage and spacecraft propulsion systems. Systems using the deeply cryogenic liquid hydrogen fuel offer the best possibilities for either upper stages or propulsive escape vehicles where the propellants are stored for only a short period of time before engine operation. On the other hand, the long-duration planetary missions requiring orbital operation and/or landing maneuvers necessitate propellant storage for months or years without excessive boiloff or freezing. Here, systems employing the more mildly cryogenic liquefied petroleum gas (LPG) fuels in conjunction with either FLOX or oxygen difluoride seem to be better than both the deep cryogenics and the earth storables.

High-energy propellant work centered on demonstrating the operational performance levels attainable in both the higher and lower pressure pump-fed engine systems, and on establishing design criteria for propulsion system components operating in a liquid fluorine environment. Supporting research was conducted on the hazards associated with the highly toxic fluorinated oxidizers.

In deep cryogenic investigations the modified pump-fed RL-10 engine demonstrated high performance at the high mixture ratios

and design criteria established for engine components operating at design conditions. Studies were conducted to evaluate the topping turbine cycle in terms of engine performance and operation and thrust chamber cooling at higher chamber pressures and area ratios.

When fluorine hydrogen engine systems are operated in the low-pressure regime suitable for pressure-fed propulsion system applications, significant kinetic losses can result during the nozzle expansion process. A program to establish the magnitude of these losses was underway. Injector hardware exhibiting maximum combustion efficiencies was tested at sea level, and simulated altitude testing, initiated in December, will determine the nozzle kinetic losses. This testing will be completed in March 1966, and the resulting experimental data will be factored into recently developed analytical models to update the theory with empirical values.

The FLOX/liquefied petroleum gas (LPG) fuels were examined for pressure-fed and pump-fed engine applications, and low chamber pressure engine performance and thrust chamber cooling techniques were demonstrated under sea level test conditions. Since cooling with the LPG fuels is more difficult than with liquid hydrogen, it was necessary to employ such techniques as transpiration cooling of the thrust chamber. (In transpiration cooling, fuel is fed through the porous walls of the thrust chamber, coating the entire internal surface of the chamber with a protective layer of propellant. Fig. 4-17.) Performance losses associated with transpiration cooling were found to be a minimum. Altitude tests to establish the effects of cooling on nozzle expansion losses as well as low-pressure kinetic losses were scheduled to start in January 1966. For pump-fed FLOX/LPG applications, the use of supercritical methane in conjunction with the topping turbine engine cycle offers possible advantages. A program to evaluate this propellant combination in the RL-10 engine, which uses the topping turbine cycle, was being negotiated.

A program was initiated to establish criteria for the design, fabrication, inspection, and servicing of flight weight components of a liquid fluorine feed system. Actual flight weight components will be tested in a fluorine test facility to verify the criteria, and the results will be documented and published as NASA standards for reference in the design of fluorine flight systems.

In the fluorine hazards programs, work was underway to establish emergency exposure limits for both fluorine and hydrogen fluoride. Analytical models for predicting atmospheric diffusion of toxic clouds resulting from launches, static firing, or from accidental spills were developed. Tests were made of methods for minimizing toxic products of fluorine combustion and for promoting rapid cloud diffusion

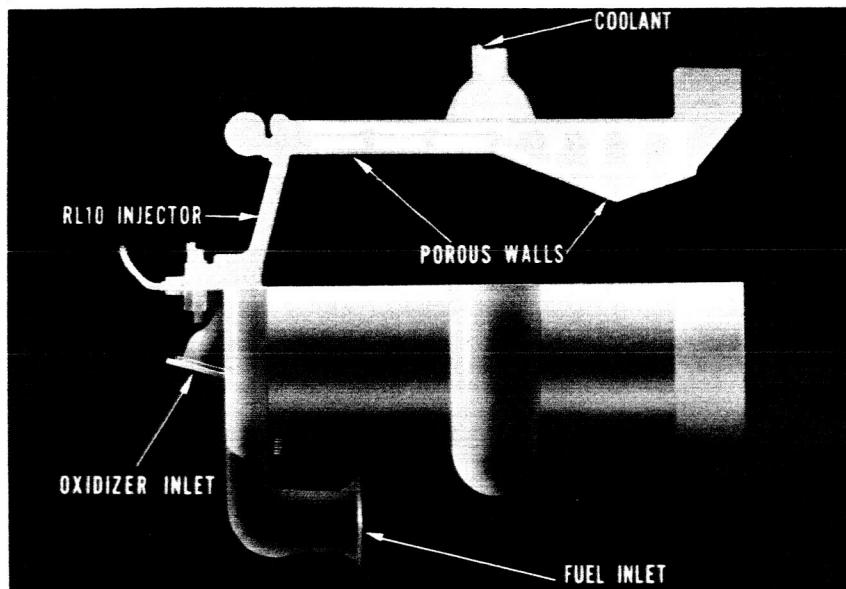


Figure 4-17. Transpiration-cooled thrust chamber.

following accidental spills. The tests used carbon containing compounds which promote combustion with fluorine and generate nontoxic carbon fluoride products.

The extended-life storable bipropellant engine work was completed in November. The unbalanced injector uncooled thrust chamber concept allowed operation at steady-state conditions for 29 minutes without exceeding temperature limits on the outside surface of the insulated thrust chamber. Also, the first phase of the hydrazine monopropellant design criteria program was completed, giving information on injector design and start response. And design of the system to use oxygen and hydrogen for auxiliary propulsion purposes was completed.

## Basic Research

### Fluid Physics

*Aerodynamic Characteristics of Meteors.*—From knowledge of reentry aerodynamics, observation of falling meteors, laboratory tests, and reentry gas dynamics analyses, it has been possible to infer the initial size and density of meteors. The data indicated that there are three ranges of meteor density corresponding to solid iron, to solid stone, and to a third class, "puff balls," having the density of plastic foam. The hypothesis that the puff balls might be produced from high-density rocks as a consequence of atmospheric entry conditions

was tested by inserting basaltic stone models into an arc wind tunnel simulating an altitude of 250,000 feet and a velocity of 60,000 feet per second. Under these conditions, the dense solid rock actually foamed as postulated. It was also found that the foam remained attached to the virgin material and built up a large diameter, high drag body with a density much lower than its original value. This and other information derived from these studies add to our understanding of meteors and of the hazard they present to long-duration interplanetary voyages.

*Magnetofluids.*—A new fluid which can be moved by magnetic forces without losing its homogeneity and fluidity was devised and its properties were being studied. This magnetofluid consists of a liquid carrier (such as kerosene) in which a microscopic dust of ferromagnetic particles is suspended. When the fluid is subjected to the forces of a magnetic field, the ferromagnetic particles become aligned with the lines of force, pulling the entire fluid toward the magnet. Heat destroys the alignment, resulting in annihilation of the magnetic forces. Thus, the principles of a power generation cycle are established. In operation, the cold fluid is sucked into a magnet by aligning the suspended ferroparticles. Inside the magnet, the fluid is heated, destroying the magnetic forces. A continuous pumping action is thus created by simply adding heat. Such a power generating cycle has the advantage of relatively low operating temperatures and possibly great endurance. Research was being conducted to improve the magnetic properties of the fluid for greater efficiency.

### Applied Mathematics

Mathematicians at the Jet Propulsion Laboratory developed a mathematical technique which was applied to the complex restricted four-body problem of predicting motions in an earth-moon-sun-spacecraft system. The resulting model makes it possible to compute spaceship motion, an essential requirement for effective planning and control of spaceship motion, especially near the moon.

### Materials Research

*Synthesis of Boron Carbide Filaments.*—Fiber reinforced materials may offer a relatively easy way to achieve significant improvements in strength over present conventional materials. Boron carbide fibers, which are better than almost all other fibrous materials in terms of high strength, low density, and high elastic modulus or stiffness, were studied for use as reinforcements in metals and plastics. Research on the synthesis and characterization of boron carbide filaments resulted in a method that produces filamentary single crystals having strengths

as high as 2 million pounds per square inch at room temperature, with only little decrease in strength up to approximately 2,000° F. However, filaments produced to date varied in their properties, and work was continued with the objective of synthesizing large quantities of filaments with uniformly high strength. Successful completion of this work could make available strong, lightweight structural materials needed for highly efficient space vehicles.

*Superalloy Embrittlement.*—Nickel- and cobalt-base superalloys—widely used in gas turbine engines and prime contenders for applications in space power system components, booster rockets, and advanced air breathing engines—were subject to embrittlement after long exposure to operating temperatures. In one alloy, the embrittlement was associated with the gradual growth of microscopic particles of an intermetallic compound, and it was found that the growth was promoted by one of the minor constituents in the alloy. Reduced silicon content substantially improved ductility after long exposure, and a new commercial melting practice was developed which can produce very low silicon content in the alloy and reduce susceptibility to embrittlement.

*Structure of Solid Surfaces.*—In solid state physics research, the Lewis Research Center studied the atomic and subatomic structure of surfaces of solids by means of electron spin resonance spectroscopy, a new and extremely sensitive probing techniques for obtaining quantitative details of local variations in the electronic structure of matter. The studies showed in detail how carbon dioxide molecules are absorbed at certain active sites on the surface of magnesium oxide. In addition to providing greater scientific understanding of the mechanisms of surface reactions in general, these studies may be applied in selecting a catalyst for carbon dioxide adsorption and subsequent regeneration of oxygen for life support systems in space.

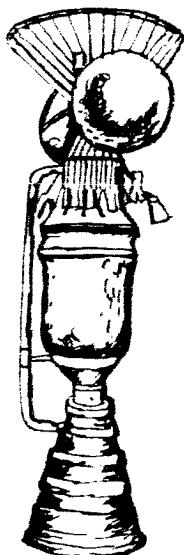
*Effect of Vacuum on Metal Fatigue.*—In an effort to collect more data about the effect of a vacuum on the fatigue of metals for use in designing machinery for long-term operation in space or on the moon, a NASA contractor made fatigue tests of an engineering alloy (aluminum) at pressures as low as  $10^{-7}$  torr (mm. of Hg.) and at temperatures as high as 200° F. Tests are to be continued at higher temperatures and to pressures as low as  $10^{-12}$  torr, and with other alloys such as titanium and steels. From the tests, two important but as yet tentative conclusions were drawn. First, evidence was strong that pressure affects the fatigue phenomenon only during the crack-growth stage, seeming to have little or no influence on the time for crack formation. Second, it was found that there is a critical pressure, below which there is little or no effect, and that the value of this

threshold pressure is dependent on temperature. Further tests were planned to obtain more data on these findings.

### Electrophysics

In research supported by a NASA grant, investigators greatly improved the power output from gaseous lasers in a frequency region formerly inaccessible at useful power levels. The increased output is related to the manner in which a molecular gas laser is excited or "pumped" so that the excised molecules are "stored" or prevented from releasing their energy until a large number accumulate; at that time the molecules are triggered to release their energy all at once. To achieve this result, the investigators used a carbon dioxide-nitrogen-helium mixture which has a sufficiently long relaxation time to permit the required energy storage. In other work, a pulse power output of several kilowatts was obtained at repetition rates as high as 500 cycles per second at a wavelength of about 10 microns in the infrared region, making possible more precise infrared spectroscopy research and thereby enhancing understanding of the electrical properties of solids and gases at this wavelength.

Researchers at the NASA Electronics Research Center obtained continuous generation of microwaves at a frequency of 12 kilomegacycles in an ultrathin wafer of gallium arsenide across which a dc potential of about 4 volts was applied. Previous work suggested that such a solid state oscillator would not operate beyond 6 kilomegacycles. Preparation of the device was achieved by very careful processing of the bulk gallium arsenide wafer which was cut from a single crystal and not epitaxially grown, and by a special method of incorporating pure tin contacts at opposite sides of the wafer. The contacts apply the exciting dc potential and also carry the oscillating output current. The oscillatory output and especially its frequency depends critically on an intimate penetration and bonding of the contacting tin layer with the gallium arsenide. Since the wafer is less than one-thousandth of an inch in thickness, the bonding must be performed with great precision. The research on this solid state microwave oscillator may prove the basis for the eventual substitution of such small and lightweight devices for heavier and costlier vacuum tubes in space communication, electronic navigation, and radar applications.



# NUCLEAR PROPULSION AND POWER GENERATION

NASA efforts in these areas, including work on the nuclear rocket program, the SNAP-8 development project (with phaseout progressing as planned), nuclear electric power, electric propulsion, and space power technology, continued to result in significant gains.

## The Nuclear Rocket Program

The joint NASA/AEC nuclear rocket program is aimed at developing the technology and systems for using nuclear rockets for advanced space missions. The greater portion of this effort is devoted to solid core reactors and engines. The program also supports, at a lower level of effort, work on tungsten reactors, nonreactor and engine system component technology, and advanced concepts.

### Graphite Reactors and Engine Systems

The graphite reactor and engine system effort of the nuclear rocket program includes the development of NERVA (Nuclear Engine for Rocket Vehicle Application) reactor and engine system technology, and the development of advanced Phoebus reactor technology.

The engine system technology program is using a nominal 1,000-megawatt reactor in a 50,000-pound-thrust ground-based engine system to determine the allowable range of engine startup characteristics,

to identify engine operating limits and component interactions, and to evaluate various control modes. The program is supported by a comprehensive component and subsystem effort which includes, as a primary objective, the development of a reactor capable of operating for about 60 minutes at full design power. The nominal specific impulse of this system is near 800 seconds, under altitude conditions assuming a 100:1 area ratio nozzle with a growth capability substantially beyond this value.

The objective of the Phoebus program is to provide a reactor of approximately 5,000 megawatts, capable of operating at higher temperatures, and thereby higher specific impulse, and at higher power densities. The 5,000-megawatt reactor is called Phoebus 2 to distinguish it from smaller KIWI-sized reactors called Phoebus 1 which are being used to explore some of the operating characteristics and design features currently planned for incorporation in the Phoebus 2 design.

The design of the advanced NERVA engine will be based upon the results of the NERVA reactor and engine system technology and Phoebus 2 reactor programs; it should provide a thrust of approximately 200,000 to 250,000 pounds.

The major work under the engine system technology program continued to be aimed at increasing the lifetime of the nominal 1,000-megawatt NRX-A reactor. This involved work to improve reactor design and the quality of reactor fuel elements. Much of this work is accomplished at the component level in the laboratory. The final evaluation of improvements, however, is obtained through full-scale reactor tests.

During the second half of 1965, significant progress was made in the development of long-duration, corrosion-resistant fuel elements. Sixty-minute tests of elements were conducted in hot hydrogen laboratory test loops. The development of a new protective technique also was demonstrated which gives real promise of greatly extending fuel-element lifetimes. Experiments using the improved elements are planned for incorporation in future test reactors.

In addition to the laboratory testing and analyses of reactor components, the NRX-A3 and Phoebus 1A reactors (tested during the first half of 1965) were disassembled and examined.

The NRX-A3 postmortem examination confirmed the ability of the reactor to operate at conditions of design power and provided valuable data for the design of future NRX-A reactors. The A3 examination also indicated that the approaches taken to improve reactor lifetime were effective. Proof of this was evidenced by the fact that the NRX-A3 components were in much better condition than

the NRX-A2 components following testing, even though the NRX-A3 was operated for a much longer duration.

The postmortem examination of the Phoebus 1A reactor also gave important data applicable to extending reactor lifetime, particularly in the core peripheral region, in spite of the fact that it was extensively damaged during the cooldown phase following the full power run because of the depletion of hydrogen coolant.

The next series of tests to be conducted in the engine system technology program will be the power tests of the NERVA "breadboard" Engine System Test (NRX/EST) assembly. (The NRX/EST was described in the 13th Semiannual Report, p. 121.) As far as can be determined, these will be the first power tests of a complete nuclear rocket engine system to be conducted anywhere in the world. Checkout of the NRX/EST was initiated on December 8, 1965; power testing is scheduled to be started in February 1966.

One of the important NRX/EST checkout experiments initiated during the report period was a series of engine cold-flow runs designed to map the early portion of engine startup to determine turbopump acceleration and shutdown characteristics. Data from these experiments compared favorably with the data obtained earlier from tests conducted on the Cold Flow Development Test System at the contractor's test facility in Sacramento, Calif.

The next series of tests to be conducted in support of the Phoebus reactor program will be the tests of the Proebus 1B reactor. These experiments are scheduled for August 1966. An objective of the 1B experiments will be to determine the ability of certain reactor components to operate at Phoebus 2 reactor thermal stress conditions. The present plans for the 1B also provide for the evaluation of a number of improved reactor components.

The work on the larger diameter 5,000-megawatt Phoebus 2 reactor during the report period primarily involved investigating problems associated with the design and scaleup of KIWI-sized components, the technology of which for the most part has been proven. The Proebus 1 reactor program contributes directly to this work. The Proebus 2 reactor was in the design stage, and the fabrication of components for the Phoebus 2 zero power critical assembly was well underway.

#### Tungsten Reactors

The objective of the tungsten reactor program is to evaluate the feasibility and performance potential of tungsten nuclear rocket engines. The Argonne National Laboratory is investigating a fast reactor concept, and the Lewis Research Center, a thermal, water-modulated concept. The emphasis of both activities to date has been on

the development of fuels material technology; it is in this area that performance potential is established.

During the second half of 1965, a 3-year program aimed at evaluating several methods of fabricating tungsten fuel elements was completed. The program yielded two processes which met the criteria established for structurally sound elements. Quantities of elements fabricated from each of these processes are to be procured during 1966 for testing in hot hydrogen loops and in reactors to determine their performance capabilities and limitations.

#### Nonreactor and Engine System Component Technology

In addition to the graphite reactor and engine system work conducted during 1965 in support of the NERVA engine technology program, continuing efforts were being made to develop the components essential to conducting the higher power Phoebus reactor tests. This work is also essential to the development of the materials and improved components required for the 200,000 to 250,000 pound thrust NERVA engine. In the development of this technology, relatively conventional hardware must be adapted for operation in a radiation environment. This environment is an added factor in the selection of materials and in the analysis of radiation heating and thermal stress problems.

A major activity of controls development has been to prove the technology of pneumatic actuators for driving engine and reactor control components. (Fig. 5-1.) This type of actuator is less subject to damage in the radiation and thermal environment of the engine than the hydraulic actuators now in hand. Tests of two prototype units were conducted in a radiation environment, either as complete actuators or as major actuator components.

Instrumentation for control, and also for diagnostic measurement, was another important program element which received continued attention. At the high powers required for reactor run durations, the effects of cumulative radiation and temperature damage on instruments are not well known. As a result, instrumentation technology is pushing the state of the art in practically all areas of measurement and will undoubtedly require new approaches to satisfy completely the needs of the program.

At one contractor's facility, work continued on the development of the axial flow pump for the Phoebus high-power reactor tests. (Fig. 5-2.) During this report period, the pump was operated for approximately 18 seconds at 34,000 r.p.m. under test conditions which exceeded the operational requirements established for the Phoebus 1 and Phoebus 2 high-power reactor experiments. In a subsequent

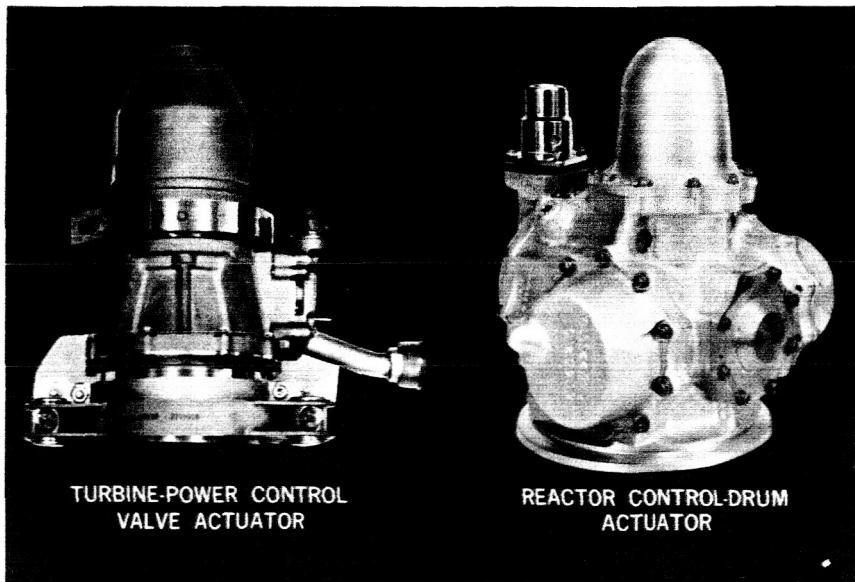


Figure 5-1. Prototypes of a pneumatic actuator.

test, however, there was a serious pump malfunction, resulting in considerable pump damage. Analyses to determine the cause of the failure were in progress at the end of the period.

At another contractor's facility, development work on the nozzle for the Phoebus 2 reactor continued. The design of this nozzle, essentially completed by the end of 1965, is a scaleup of the U-tube nozzle used for the NRX-A2 and A3 tests except that it is made of Hastelloy X instead of stainless steel.

#### Advanced Concepts

In addition to the research and development work being conducted on solid-core reactors and engines, the nuclear rocket program also continued to support, at a very low level, the basic studies on the dust bed, liquid, and gaseous cavity reactor concepts. These studies are being conducted primarily to explore some of the basic questions associated with establishing the feasibility and performance capabilities of these systems.

#### The SNAP-8 Development Project

NASA is continuing with its planned phaseout of the SNAP-8 power conversion system development, using fiscal year 1965 funds. The principal activities included in phaseout are performance testing

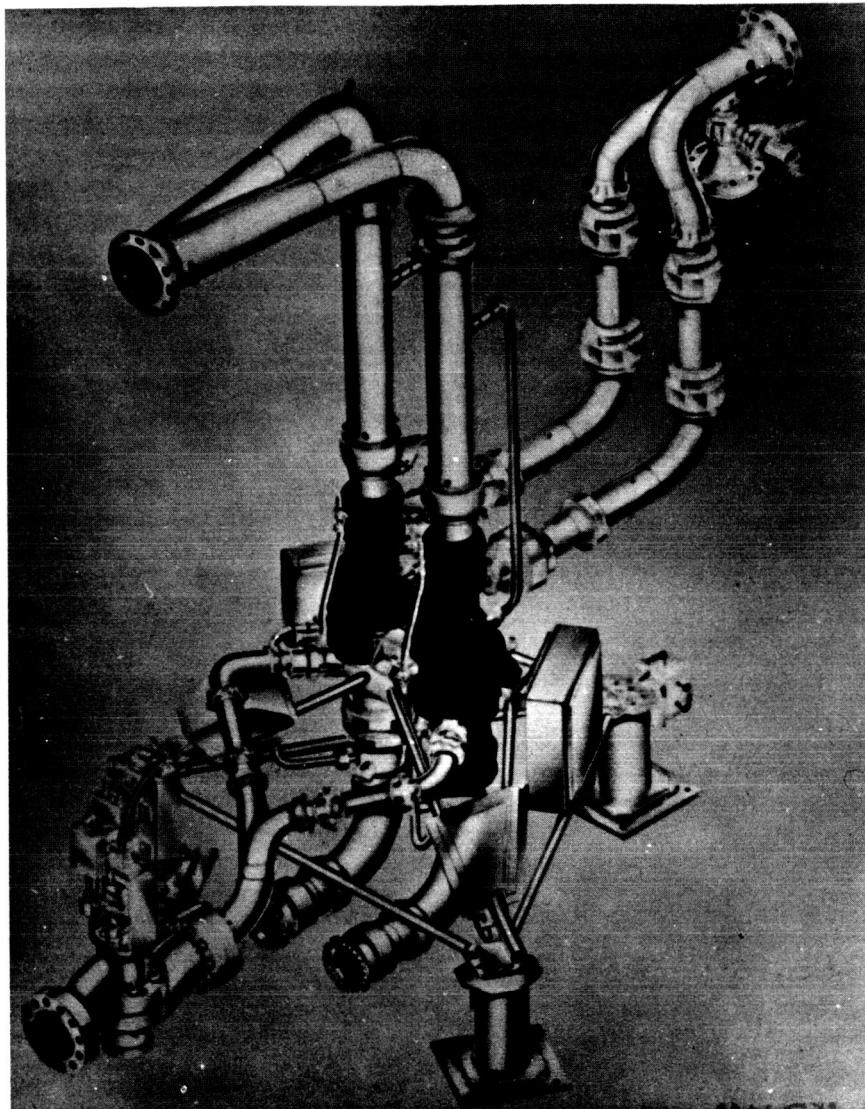


Figure 5-2. Axial flow pump for the Phoebus reactor.

of major components and operation of a breadboard power conversion system for as long as possible, hopefully 10,000 hours.

A planned 3,000-hour test of the reactor loop pump was completed and over 3,500 hours of operation were accumulated on the lube and coolant pump. Testing of a new boiler model was initiated; this model had been redesigned to improve its mechanical features and to correct

thermal performance deficiencies at startup. Results indicated that improvement resulted from the redesign but further efforts are required. A test of the turbine alternator was terminated after 830 hours because the turbine failed. A unit modified to correct the deficiency was ready for testing at the end of the period.

Preparations to investigate steady state performance of the first power conversion system at 35 KWe were underway and testing was expected to begin in early 1966.

### Nuclear Electric Power Research and Technology

The nuclear electric power research and technology program is aimed at providing the energy conversion technology necessary to build future nuclear electric power generating systems. Such systems are required to be lighter weight, with higher power outputs to operate for much longer time periods than the systems currently being developed. They would be used for two general purposes: To provide the power for electrical rocket engines and to provide onboard power for spacecraft, lunar and planetary base power, and orbiting space stations.

Specific technology areas within this program include work on advanced Rankine turbogenerators, thermionic conversion, low power Brayton cycle equipment, and isotope power.

#### Rankine Turbogenerator Technology

Performance tests of the two-stage potassium vapor turbine were completed and the data were analyzed. The turbine performance generally conformed with design predictions. The test facility and test turbine were the first of their kind to be constructed. A 2,000-hour endurance test of the same turbine was also completed in late December, and at the end of the period, the test unit was disassembled for inspection. The test objective was to determine long term erosion effects at low vapor wetness; very little damage was revealed by the post-test inspection.

A program started in 1961 to obtain basic heat transfer data for boiling and condensing potassium at high temperatures (up to 2,100° F.) was completed; over 7,500 hours of useful testing were included in the program. The program established the basic heat transfer information needed to design compact (and lightweight) boilers and condensers for the advanced Rankine turbogenerator system.

A boiling potassium corrosion loop (maximum temperature 2,100° F.) constructed of an advanced columbium-base alloy successfully completed a 5,000-hour test. Numerous advanced materials test-

ing and materials development programs for electrical components, turbines, pumps, and radiators were continuing.

Ten-thousand-hour tests of a number of high-emittance coatings for space radiators were completed at a contractor's facility. A number of potentially suitable coatings for operation in the 800°-2,000° F. range were found.

### **Thermionic Conversion Technology**

A series of (thermionic) fuel irradiation test programs was started at the NASA Plum Brook Test Reactor; these tests were in progress at the end of the period.

Thermionic materials research programs were continuing. Attempts were being made to increase the strength of the tungsten emitter materials by alloying, special metallurgical processing, and the like. Nonnuclear metallurgical and chemical compatibility tests (of up to 10,000 hours duration) were continuing to be performed with contender fuel, emitter, and insulator materials. Emission tests (of 1,000-hour duration) have indicated that tungsten cladding is stable (1) with mixed zirconium-uranium carbide fuels to 1,900° C., (2) with uranium dioxide fuel to above 2,000° C. The tungsten/26-percent rhenium alloy, in addition, proved to be compatible with uranium dioxide at 1,800° C. for a period of 5,000 hours.

### **Low-Power Brayton Cycle Equipment**

During this period, experimental testing continued to obtain the performance characteristics of radial flow turbines and compressors intended for use in systems with power levels of about 10 electrical kilowatts. The results to date have been encouraging; during this period the test efficiencies coincided with contractor-predicted values which were previously in question. A gas bearing-supported radial flow turbocompressor was also delivered to NASA-Lewis by the contractor. (Fig. 5-3.) At the period's end, the unit was being installed in Lewis facilities for "hot gas" testing. Delivery of the axial flow turbine and compressor research units is scheduled for mid-1966.

### **Isotope Power**

The AEC was continuing with development of the SNAP-19 which is to be used to provide supplementary power for the Nimbus B satellite. Delivery of electrically heated prototype units to NASA for investigation of spacecraft integration problems is expected by mid-1966.

The most significant development in this period consisted of the selection by the Manned Spacecraft Center of an isotopically fueled

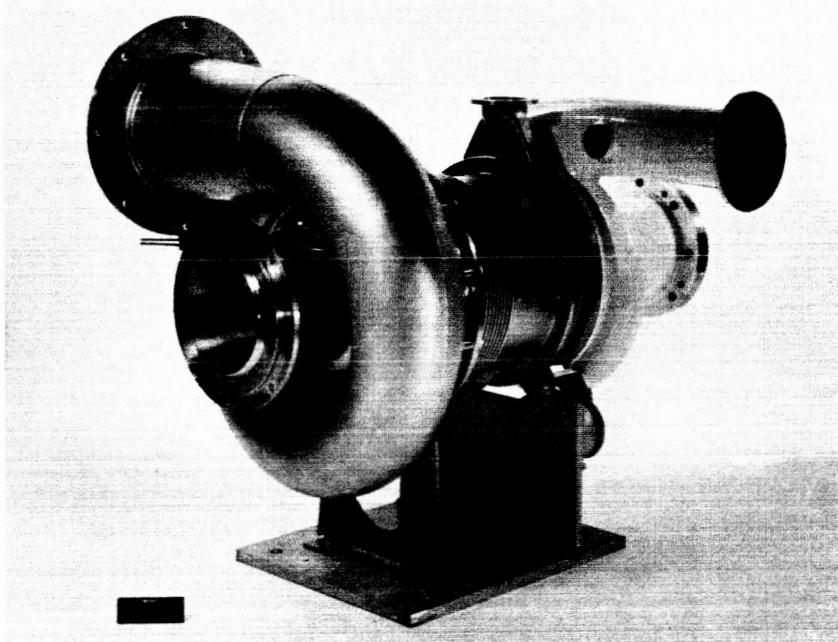


Figure 5-3. Gas bearing-supported radial flow turbocompressor.

generator, designated SNAP-27, to power the Apollo Lunar Surface Experiment Package (ALSEP). This equipment is to be placed on the lunar surface by the Apollo astronauts and will automatically measure and transmit scientific information back to earth for a year after the astronauts' departure. A contract has been let by the AEC for the development of SNAP-27 and the AEC's contractor is co-ordinating its work with the NASA ALSEP contractors.

Work was initiated on an advanced isotope power unit to demonstrate higher electrical output per pound and to provide for more efficient use of short half-lived isotopes. Thermionic converters will be used to generate electrical power from the thermal energy generated within the isotopes fuels. A 1,000-hour compatibility test of materials to be used in the heat rejection components was completed. The thermionic converters are expected to go on test in 1966.

### The Electric Propulsion Program

The electric propulsion (electric rocket engine) program provides the research data and advanced technology for development of electric thruster systems. This program is composed of two elements: Electric propulsion system analysis and experimental evaluation, and

research and technology efforts on the three main types of electric thrusters.

### System Analysis and Experimental Evaluation

Early studies (*13th Semiannual Report*, p. 127) led to identification of the Applications Technology Satellite (ATS) control requirements as being appropriate to electric propulsion. Lewis Research Center is presently developing a small (15-watt) ion engine as a back-up for the east-west stationkeeping of the synchronous ATS D&E flights. A resistojet system is also being developed as a backup for inversion of this spacecraft.

It is presently planned to fly the ion engine as an experiment on the earlier ATS-C spacecraft. If schedule permits, this test will be moved up to the ATS-B flight. In anticipation of this eventuality the ion thruster underwent integration with the spacecraft at the contractor's facility. This flight test will enable NASA to evaluate long-time performance of the system in the space environment. It will also determine whether there are any radio frequency interference effects between the ion system and the spacecraft communications system. If the tests are successful, they would represent the first application of this new technology to the ongoing NASA program.

Because of these efforts on ATS, NASA was able to defer the SERT III flight since the objectives of that program may be fulfilled here and in later planned ATS flights. The purpose of SERT III would be to evaluate various electric thruster systems for satellite station-keeping and attitude control.

A second possible early application of electric propulsion is in drag cancellation and attitude control of large space stations. A study effort under the direction of Langley Research Center (*13th Semiannual Report*, p. 129) is using the MORL space station as a vehicle for comparing various systems for this application. Preliminary results were encouraging and have led to suggestions for further experimental verification. This testing is to be initiated in the coming period.

A third possible application of our current thruster technology is in solar-powered midcourse propulsion for unmanned planetary spacecraft. A comprehensive study effort, based on technology that is either demonstrated or within reach, was carried out under JPL direction during the past year. To date, this study has shown that a spacecraft designed with an electric propulsion system using lightweight solar arrays and employed for midcourse application would permit the spacecraft to carry a greater payload than would be possible if a chemical propulsion system were used. For example, in the case of the

Voyager Mars mission using the Saturn IB-Centaur, a fourfold increase in the weight available for orbital scientific payload would be achievable.

In view of the potential gains resulting from the use of such systems, studies involving other launch vehicles and missions will be carried out. The objective will be to arrive at a single spacecraft concept for each candidate launch vehicle, suitable for a variety of missions within the range of capability of the launch vehicle. Propulsion system verification hardware is presently being integrated for an initial 500-hour test to further demonstrate feasibility.

The SERT II orbital flight program, which has as its objective the verification of ion thruster system technology in the space environment for long-term operation, is still in the planning stage at Lewis, due to overall NASA budgetary considerations.

### Thrustor Research and Technology

In this second element of the program, continuing investigations of three types of thrustors, electrostatic or ion, electrothermal or resistojet, and plasma were carried out.

With the fully satisfactory completion of endurance testing of the cesium autocathode electron bombardment ion engine (*13th Semi-annual report*, p. 129), a major milestone in ion thruster development had been reached. A second engine has since surpassed that mark, and a third test with a life objective of 8,000 hours was initiated. Significant progress on the Mercury electron bombardment engine toward the development of a satisfactory cathode was also made. (Fig. 5-4.) A mercury pool cathode demonstrated a life of better than 2,500 hours with no apparent deterioration. Oxide cathodes also progressed, with current test times at Lewis in excess of 2,000 hours.

An electrothermal thrustor of the pulsed resistojet type was under development for the ATS application. With an easily storable propellant, such as ammonia, such thrustors offer the potential of materially reducing the weight required for spacecraft attitude control systems for a wide range of missions.

The guidance derived from the earlier mentioned MORL study led to a decision to extend the life capability of steady state resistojets. Present plans call for testing to demonstrate life of 2,100 hours or more. It is also planned to investigate the possible use of waste from life support systems as a propellant, thus permitting further system weight reductions.

Plasma devices are less developed than the electrothermal and electrostatic schemes; however, they hold promise of combining the high specific impulse capability of ion engines with the high thrust of the



Figure 5-4. Mercury electron bombardment engine.

electrothermal engines and thus justify study of their engineering feasibility.

Research continued on two classes of devices, steady flow and pulsed, which differ primarily in the way the electrical energy is delivered to the accelerator. In plasma thrusters, an ionized gas is accelerated by the forces of interaction between currents within the gas and magnetic fields. Propulsion efficiency of the pulsed coaxial gun was confirmed to be about 60 percent at 5,000 seconds specific impulse. However, a reliable propellant valve is as yet unavailable, and power conditioning remains a subject for future research.

Some progress was made in understanding macroscopic behavior of the magneto plasmodynamic (MPD) arc, and further attempts to define test chamber influence on performance were made. These devices show promise of evolving into thrusters which are simpler in configuration and superior in performance to the ion engine.

## Space Power Technology

Systems using solar and chemical energy have supplied the electricity to power all NASA-launched vehicles and spacecraft from 1958 through 1965. During this period, solar and chemical power research and technology efforts continued with emphasis on these objectives: increasing the power level (hence size); reducing the weight of photovoltaic arrays; significantly improving the energy, density, and cycle life of rechargeable space batteries; and extending the operating life of fuel cells.

### Solar Cells

The largest solar cell arrays used in space by NASA have been less than 80 square feet in area, producing slightly less than 700-watt output power. The increased payload capability of larger launch vehicles such as the Atlas-Centaur, uprated Saturn I, and Saturn V will make it possible to use electric power systems capable of several kilowatts output. In a 10-month design study of high-power solar cell arrays completed during this period, the feasibility of solar cell systems capable of providing up to 50-kilowatt output from a 5,000-foot array weighing less than 2,500 pounds was studied. A promising foldup array design was evolved; its feasibility will be verified following fabrication and test of an experimental breadboard array.

A small number of experimental silicon solar cells with both the negative and positive electrical contacts on the side away from the sun were fabricated, and plans were made to assess the economic feasibility of manufacturing such cells in large quantities.

Investigators determined that thin (1 to 2 mil thick) glass covers can be deposited directly on the light-sensitive surface of silicon cells. Such integral glass covers offer the possibility of greater economy and durability and lighter weight than the more conventional 6-mil cover which is applied with a transparent silicon adhesive. Consequently, work continued to scale these small laboratory processes up to practical production techniques.

### Thermionics

A significant achievement during this report period was the operation, for the first time, of a thermionic converter for over 10,000 hours at temperatures between 1,900° and 2,100° K. This milestone is an important step toward the needed operating lifetime of 20,000 to 30,000 hours.

### Solar Energy Collection and Storage

Before precision metal-forming techniques can be extended to solar concentrators about 60 inches in diameter, an accurate master (convex

tool over which the forming operation can be performed) is required. Spin casting, which appears to be the most promising method for economical fabrication of large masters, was demonstrated to be feasible in an earlier exploratory effort (NASA *11th Semiannual Report*, p. 92). Although the test did not result in a fully useful master for high performance concentrators, the experience obtained was applied to the manufacture of a second generation master (also 9½-foot diameter) currently being experimentally evaluated. Optical ray trace data indicated a substantial improvement in the surface accuracy of this second generation spin casting.

Development of the aluminum electroforming process for lightweight, high-performance, nonmagnetic concentrators (NASA *12th Semiannual Report*, p. 87) continued with emphasis on improving the structural characteristics of the thin aluminum deposit.

Marked progress was made in obtaining basic thermophysical data on thermal energy storage materials being considered for use in high-temperature energy conversion systems. Particularly useful data were collected on the latent heat of fusion and thermal expansion of beryllium-magnesium oxide (3BeO-2MgO), the material of principal interest for solar thermionic application.

### Batteries

This work focused on investigations of the silver oxide electrode which is important for space batteries because (1) it can replace the magnetic nickel oxide electrode, thus providing a nonmagnetic battery for space science measurements of weak magnetic fields; (2) with a cadmium anode, it yields three to four times the energy density of the extensively used rechargeable nickel oxide-cadmium battery; and (3) with a zinc electrode, it is the primary (nonrechargeable) battery of highest energy density available.

However, there are difficulties with the discharged silver oxide cathode. One is that it dissolves in the electrolyte and migrates to the anode. To prevent this migration, thin polymer separators can be used, but most available polymers react chemically with the electrode and electrolyte and soon become useless. In a relatively severe test, cellophane separators failed after 15 cycles, and after 30 cycles all the cells in a particular battery had failed. Efforts to improve separator materials resulted in a separator which withstood 80 charge-discharge cycles under the same severe test conditions.

Another difficulty in these tests, made on cells with silver oxide cathodes and zinc anodes, was that the zinc anode went into solution in the electrolyte much faster than the silver. When the zinc was re-plated on the anode during recharging, the deposit was not uniform,

and zinc needles were frequently formed. These needles can puncture the separator and grow to join the cathode side, thus short-circuiting the cell. In research on this problem, it was learned that zinc needles form at charging potentials of about 1.8 volts while a mossy kind of zinc deposit forms at charging potentials of 1.65 volts. Although this deposit does not pierce the polymer separator, it does grow through it and short the cell. However, interrupted charging greatly reduced this moss penetration through the separator, suggesting that uneven concentrations of zinc ions in the solution cause the problem and that it might be overcome by improved charge control.

### Fuel Cells

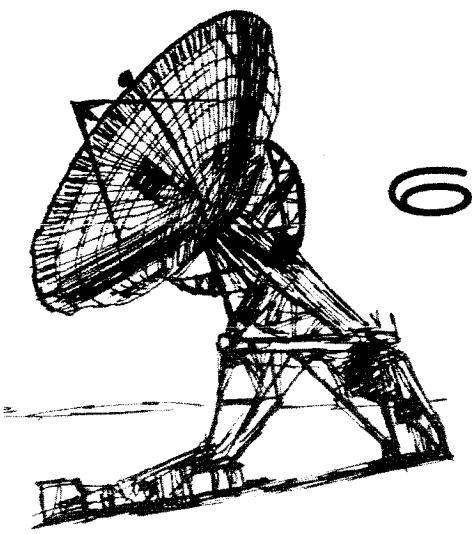
Research in this area led to the development of high-performance catalyzed electrodes that can be used either at very high energy densities (over 1,000 milliamperes per square centimeter) or at high efficiencies under normal working conditions. Work was also started to define the best operating conditions for these electrodes and to determine their behavior in lengthy operation. To control corrosion and humidity, which have a significant effect on longevity, a light gold plating was applied to the nickel parts for corrosion protection, and the humidity in the hydrogen and oxygen streams was regulated. As a result the degradation in performance of single cells was lowered from 10 millivolts (mv.) per 100 hours to 1.2 millivolts under otherwise equal operating conditions and after a period of 740 hours. Such results translated into system performance for 30 cells working in series for 2,000 hours would mean a drop of less than three-fourths volt which would be within voltage specifications. Without corrosion and humidity control, voltage could drop 6 volts, which is below acceptable levels.

Research was started on an electrolytically rechargeable fuel cell made up of a 500-watt, 600-watt-hour stack of 34 cells that alternately act as a fuel cell and as an electrolyzer. Operating at 55-percent thermal efficiency, the experimental unit was delivering about 6-watt-hours per pound. It was cycled 100 times and delivered up to 700 watt-hours on 1 discharge. Further work was planned on problems such as corrosion of nickel electrodes and impurities introduced into the caustic electrolyte solution from its asbestos retaining mat.

A book prepared for NASA under contract was completed during this period. It reviews and evaluates all Government-sponsored fuel-cell research from the early 1950's through 1963, describing the results, analyzing the meaning and significance of the work, and recommending future actions.

**Electrical Systems Technology**

A fast switching, high-power transistor capable of handling 100-ampere currents was developed. Its low switching time (less than 3 microseconds) offers benefits in the form of reduced switching losses and reduced weight and size of associated reactive elements. Such an advance in one of the circuit elements can be the basis for significant improvements in the performance of power conditioning equipment for spacecraft electrical systems.



## TRACKING AND DATA ACQUISITION

The NASA tracking networks successfully supported 55 missions during this period. Twenty-eight of these were launched prior to 1965. Some of the more important flights supported were Gemini VII, Gemini VI-A, and Mariner IV.

One of the most significant events during this period was the transmission to the Earth of photographs of the Mars surface by Mariner IV. Also of significance was the realtime simultaneous control of two spacecraft during the rendezvous maneuver of Gemini VII and Gemini VI-A.

Planning and implementation of the networks continued, primarily in preparation for Apollo missions. New stations were being constructed, ships and aircraft were being modified, equipment was being purchased and installed, and technicians were being trained to operate and man the new equipment and stations.

### Manned Space Flight Network

The Manned Space Flight Network, now actively supporting the Gemini program, is being implemented for the Apollo missions which are scheduled to begin during the upcoming year. During this period the network supported the Gemini V, Gemini VII, and Gemini VI-A missions.

The network for support of Gemini missions includes the following ground stations and ships: Cape Kennedy, Fla.; Bermuda; Grand

Canary Island; Tananarive, Madagascar; Carnarvon, Australia; Kano, Nigeria; Canton Island; White Sands, N. Mex.; Eglin, Fla.; Point Arguello, Calif.; *Coastal Sentry Quebec* (ship); Hawaii; *Rose Knot Victory* (ship); *Range Tracker* (ship on loan from DOD for specific missions); Guaymas, Mexico; and Corpus Christi, Tex.

The flexibility of the network was successfully demonstrated during the Gemini VII and Gemini VI-A rendezvous mission. Preparations had previously been made to support the Gemini VI and the Agena Target Vehicle; however, when the Agena failed and the decision was made to proceed with the rendezvous mission, the network capability was used for tracking and communicating with two spacecraft and the four astronauts.

During this period construction of facilities required for support of the Apollo program was completed at stations in Guam (fig. 6-1); Carnarvon, Australia; Bermuda; Cape Kennedy; Guaymas, Mexico; Hawaii; and Ascension Island.

Installation of unified S-band equipment in various stations continued during this period. The unified S-band system represents an important step forward in upgrading station instrumentation. The basic feature is that the system uses a single carrier frequency to the

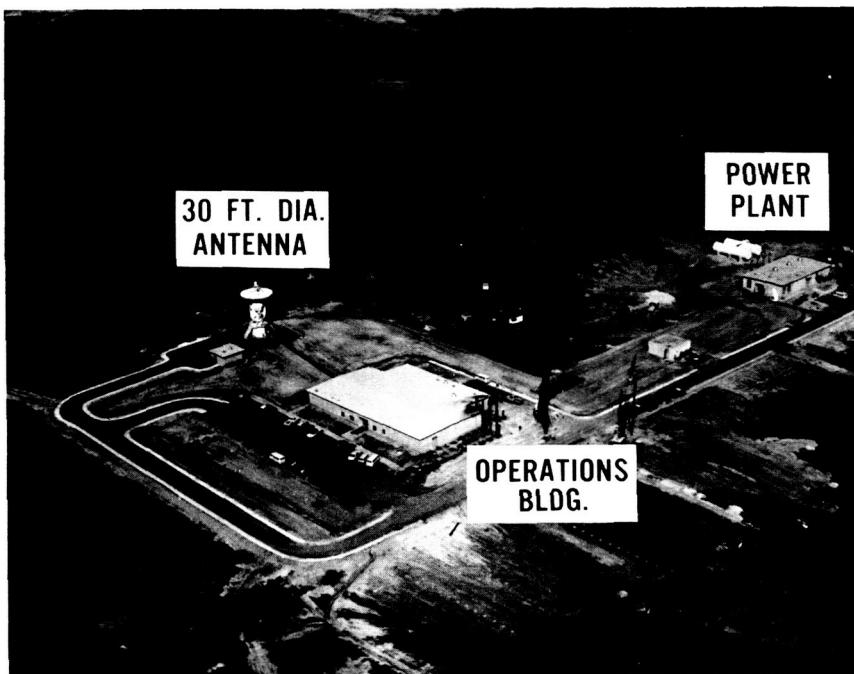


Figure 6-1. Station at Guam for manned space flight support.

spacecraft and one back to earth to provide tracking as well as communications with the spacecraft, thus reducing the frequency channel requirement. This also reduces the equipment required aboard the spacecraft. The system will provide more reliable tracking and communications to lunar distances to meet Apollo program requirements.

The Apollo instrumentation ships program to provide five ships—the *Vanguard*, *Redstone*, *Mercury*, *Huntsville*, and *Watertown*—progressed satisfactorily. The ships, now being modified, will provide functions of tracking, communications, telemetry, navigation, and data processing.

In October, a contractor was selected to modify and instrument eight C-135 jet aircraft. (Fig. 6-2.) These are the Apollo range instrumentation aircraft which will be deployed over the Atlantic and Pacific Oceans to provide voice and telemetry transmission from the spacecraft to the ground network. Work is being done under the

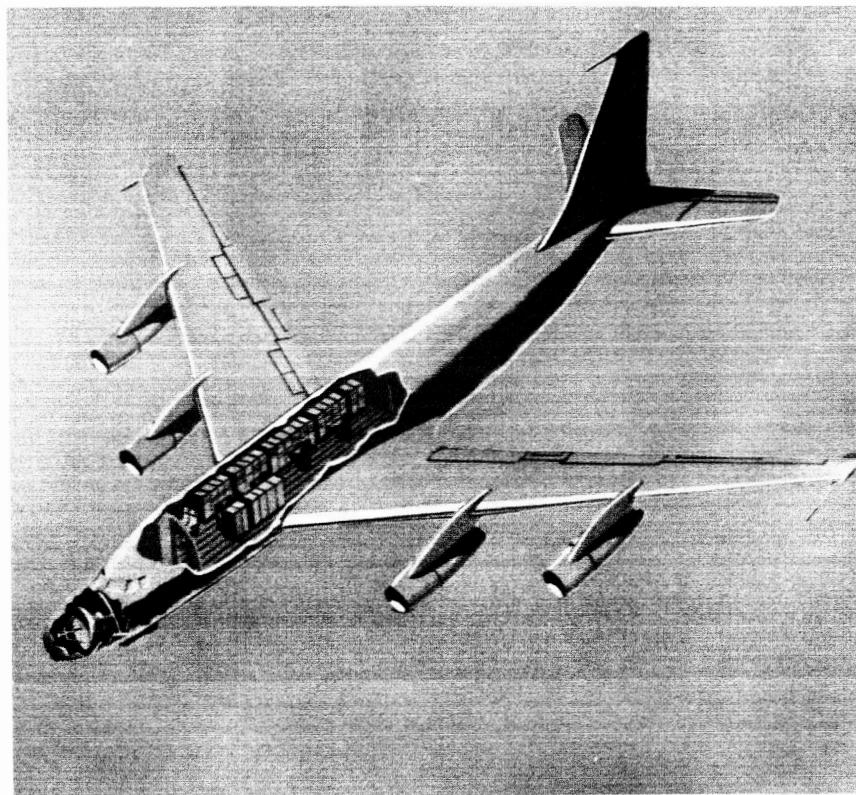


Figure 6-2. Apollo instrumented aircraft; cutaway section shows consoles for mission coordinator, communications, telemetry recording, R-F subsystems, and central timing.

supervision of the Air Force for NASA. The first three aircraft are scheduled to be operational early in 1967, with all aircraft to be fully operational by the end of 1967.

### Deep Space Network

The Deep Space Network is a precision ground instrumentation system which provides control, tracking, and data acquisition support for spacecraft during unmanned lunar and planetary missions.

The present operating network consists of 85-foot antenna facilities located at Woomera and Canberra, Australia; Johannesburg, South Africa; Goldstone, Calif.; and Madrid, Spain. A launch checkout station at Cape Kennedy, Fla., and the Space Flight Operations Facility (Control Center) located at the Jet Propulsion Laboratory in Pasadena, Calif., complete the network.

Three stations in the network, located at Goldstone, Canberra, and Madrid, are to be modified and equipped to back up the Manned Space Flight Network during the lunar flights of the Apollo program. This work was progressing on schedule.

During the period, the network supported two major flight missions—the Pioneer VI and the Mariner IV. The Mariner IV, launched on November 28, 1964, was tracked continuously until it accomplished the fly-by of Mars on July 14, 1965, and then for about 2½ months thereafter. Twenty-two photographs of Mars were transmitted to the ground through network facilities at Goldstone and Pasadena, Calif. A two-way communication record of 191 million miles was established between the spacecraft and ground stations. The previous communications distance record set by the United States was approximately 54 million miles. This occurred after the Mariner II fly-by of Venus in 1962. In December 1965, a one-way record of 210 million miles was established when transmitted signals from the Mariner IV spacecraft were received by the Goldstone station.

In addition to the pictures transmitted to Earth of the Mars surface, a most significant accomplishment was the occultation experiment which provided data for studying the Martian atmosphere. This experiment involved the precise measurement of telemetry signals as the spacecraft entered the Martian atmosphere before passing behind the planet and again when it came into view. The analysis of the data acquired enabled scientists to make important inferences about the atmospheric pressure on Mars.

Pioneer VI was launched on December 16. The network was supporting this mission at the end of the report period.

Construction work continued on the first U.S. 210-foot advanced antenna system at the Goldstone, Calif., station, shown in figure 6-3. Antenna erection was completed in September. (*13th Semiannual Report*, ch. 6.)

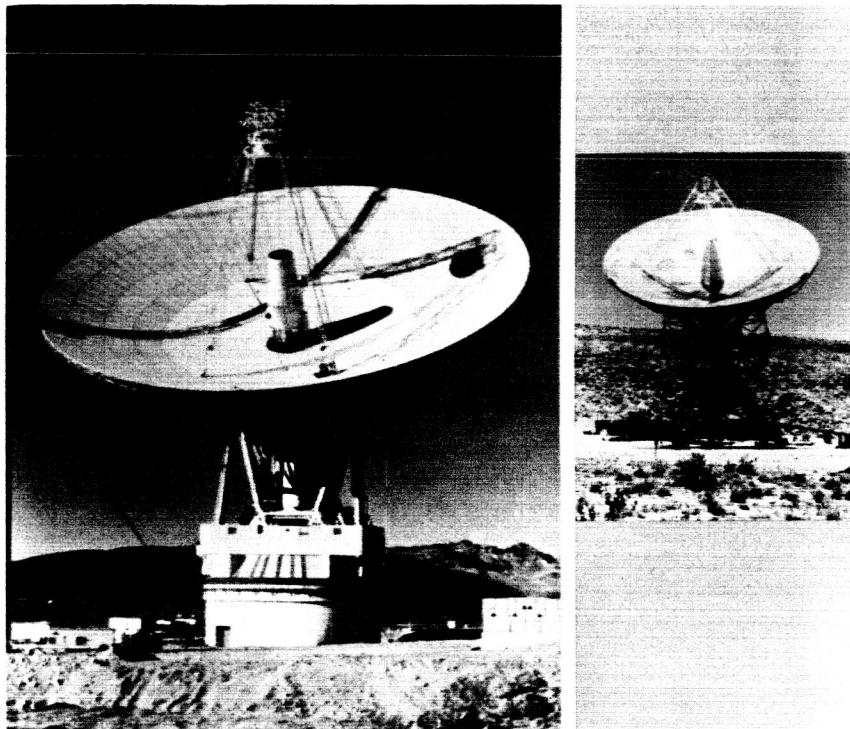


Figure 6-3. Goldstone 210-foot-diameter antenna in contrast with a typical 85-foot-diameter antenna.

### Satellite Network

The Satellite Network provides support for the unmanned scientific, communications, and meteorological satellite programs. At the present time, the network consists of facilities at 16 U.S. and foreign locations and a control center. These facilities provide ground electronic systems which track, acquire experiment and housekeeping data from the satellite, determine the status of each satellite, and command the satellite functions. Locations are as follows:

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<i>United States</i>	<i>Foreign countries</i>
Fort Myers, Fla.	St. John's, Newfoundland
Blossom Point, Md.	Winkfield, England
Fairbanks, Alaska	Johannesburg, South Africa
Goldstone, Calif.	Tananarive, Madagascar
East Grand Forks, Minn.	Carnarvon, Australia
Rosman, N.C.	Woomera, Australia
	Canberra, Australia
	Quito, Ecuador
	Lima, Peru
	Santiago, Chile

These NASA stations are supplemented by optical camera tracking stations operated by the Smithsonian Astrophysical Observatory under a grant from NASA to the Smithsonian Institution. The optical stations obtain data for research purposes via precision orbital determination and provide backup support to the NASA stations during launch and early orbit tracking of satellites.

The Satellite Network supported 50 satellite programs during this period. Eleven of these satellites were launched since July 1, 1965, as follows:

<i>Name</i>	<i>Date launched</i>
1965 51A (TIROS X)-----	July 2, 1965.
1965 58C (ORS-3) <sup>1</sup> -----	July 20, 1965.
1965 60A (Pegasus-C)-----	July 30, 1965.
1965 63A (EGRS-5) <sup>1</sup> -----	Aug. 10, 1965.
1965 65E (Temsat) <sup>1</sup> -----	Aug. 13, 1965.
1965 81A (OGO-C)-----	Oct. 14, 1965.
1965 89A (GEOS-A)-----	Nov. 6, 1965.
1965 93A (IQSY—Explorer 30)-----	Nov. 19, 1965.
1965 98A (ISIS-X) (DME-A)-----	Nov. 29, 1965.
1965 98B (ISIS-X) (Alouette-B)-----	Nov. 29, 1965.
1965 101A (FR-1)-----	Dec. 6, 1965.

<sup>1</sup> Department of Defense satellites.

At Canberra, Australia, a new 85-foot antenna became operational in September. This station provides data recovery in the Far East longitudes for highly eccentric observatory spacecraft and rounds out the prime support for the Orbiting Geophysical Observatory (OGO) program. The Rosman, N.C., station's second 85-foot antenna system became operational in July. (Fig. 6-4.) This station is equipped to handle anticipated support requirements for the great majority of the satellite programs. At Tananarive, Madagascar, facilities for meeting satellite injection requirements became operational in September. This facility supports manned space flight missions, the OGO and IMP spacecraft, and other scientific satellite programs.



Figure 6-4. Tracking and data acquisition station, Rosman, N.C.

### Network Communications

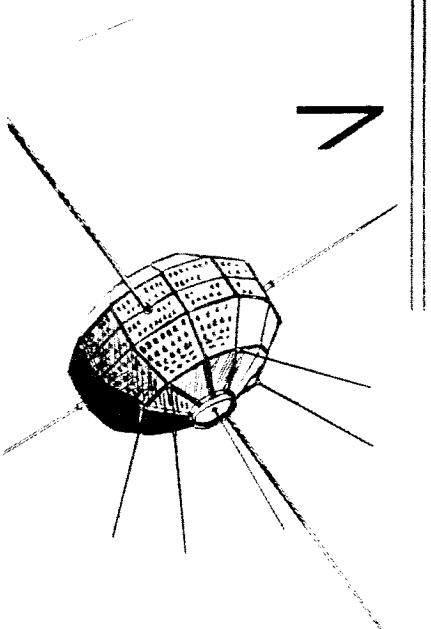
The network stations are linked to each other and to control centers by an extremely reliable, high capacity NASA Communications Network (NASCOM). (*13th Semiannual Report*, ch. 6.) The NASCOM successfully supported all program requirements of NASA and other agencies during the period.

Looking to the future, much effort was directed toward meeting the communications requirements of the Apollo program. For the extremely complex manned lunar missions, realtime operational control will be maintained in the mission control center where large-scale data processing facilities and technical specialists will assist the flight director in exercising mission control. This requires a markedly increased amount of fully reliable communication links to all land stations and ships.

From studies conducted with the National Communication System (NCS), it became evident that the Apollo communication requirements could not be met by conventional systems alone but could be met through the addition of a communications satellite system. As a result, NASA in June 1965 requested the manager of the NCS to initi-

ate discussions with the Communications Satellite Corp. to determine whether they could provide the required service. During the reporting period, a proposal was submitted by the Communications Satellite Corp. and evaluated by a NCS working group. As a result of this evaluation, the Secretary of Defense, who is the executive agent of the NCS, authorized NASA to negotiate with the Communications Satellite Corp. for the required communications services. These negotiations were in progress at the end of the reporting period.

As part of the expansion of communications services to meet project requirements, switching equipment is being installed at major communications focal points. During 1965, automatic high-speed switching equipment was installed in Canberra, Australia, and was being installed in London at the end of the year.



## **INTERNATIONAL AFFAIRS**

NASA international program activities included the launching of two additional international satellites, conclusion of the first agreement for a cooperative satellite with Germany, the flying of three contributed foreign experiments on NASA satellites, the continued launching of international cooperative sounding rockets, and the extension of operational support facilities for NASA satellite missions in other countries. The Agency also continued providing advice to the Departments of State and Commerce on the export of aerospace equipment and technology, circulated abroad an invitation for international space cooperation, and expanded its international personnel and information exchange activities.

## Cooperative Projects

Alouette II and FR-1, designed and built by Canada and France, respectively, became the fifth and sixth international cooperative satellites. An agreement for the first international cooperative satellite with Germany was concluded, thus bringing the total of such agreed satellite projects to 14. One French and 2 British experiments were launched on NASA scientific satellites, and some 20 launchings took place as part of cooperative international sounding rocket projects. New sounding rocket projects were agreed to with Argentina, Brazil, India, and Norway.

### Argentina

A memorandum of understanding was signed with the Argentine National Commission for Space Investigation (CNIE) providing for continued cooperation in investigating the physical processes which produce the ionospheric phenomenon known as "Sporadic E." Two daytime and two nighttime launchings of electron density and temperature and ion density payloads are planned from the Argentine launching range at Chamical in 1966.

### Brazil

Three sounding rocket experiments undertaken cooperatively by the Brazilian National Space Commission (CNAE) and NASA were successfully launched: two from the Barreira do Inferno range near Natal, Brazil, on December 15 and 18, and one from Wallops Island on August 24. The purpose of these experiments was to study cosmic ray effects on the lower ionosphere.

CNAE and NASA also agreed on two other cooperative sounding rocket projects during this period. In the first project, synoptic launchings of meteorological sounding rockets will be conducted from Brazil along with launchings taking place in the United States and Argentina. (A similar agreement was concluded earlier in the year with the Argentine Space Commission.) This agreement anticipates the establishment of an inter-American experimental meteorological rocket network (EXAMETNET), with launching stations in a Western Hemispheric chain from southern Argentina to Canada.

The second agreement provides for the launching of 12 NASA "grenade" sounding rocket experiments from the Barreira do Inferno range to obtain wind, temperature, and other meteorological information in the 40- to 100-kilometer region of the atmosphere.

First launchings in both of these projects are scheduled for early 1966.

**Canada**

As part of the ISIS (International Satellites for Ionospheric Studies) program with Canada, NASA launched the ISIS-X payload (consisting of the Canadian Alouette II and the NASA direct measurement Explorer-A spacecraft) from the Western Test Range on November 28. (Fig. 7-1). This launching was the second in a series of five to be conducted in the program, the overall purpose of which is to provide information on the ionosphere throughout an 11-year period from solar minimum to solar maximum. The first satellite in the program, Alouette I, was launched in September 1962 and, at the end of the reporting period, was operating normally more than 3 years later—thus establishing a reliability performance record. The last three satellites in the series are scheduled to be launched in 1967, 1968, and 1969.

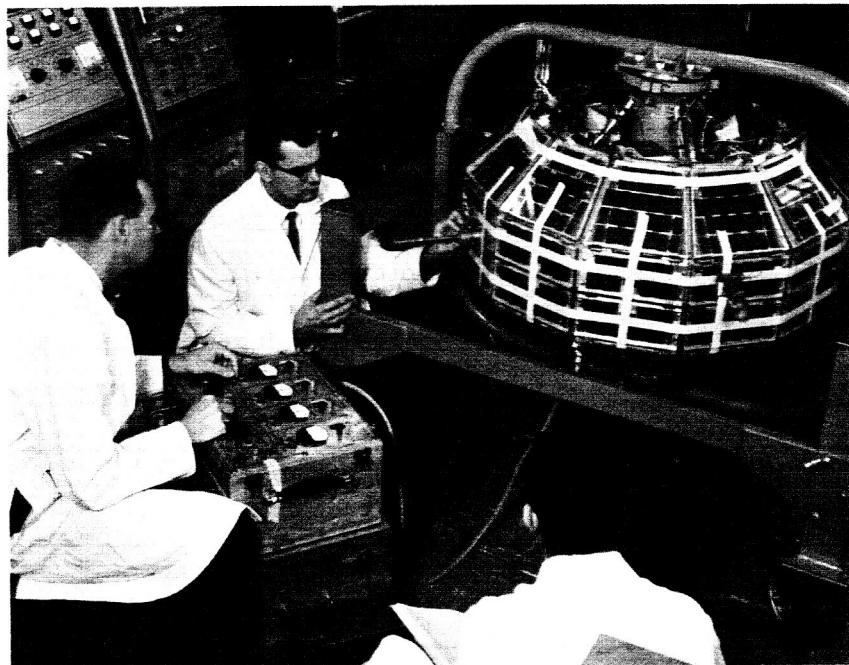


Figure 7-1. Alouette II prototype being checked by NASA technicians.

### **European Space Research Organization (ESRO)**

Substantial progress was made in implementing a previously agreed cooperative satellite program between ESRO and NASA. NASA plans to launch two ESRO-built satellites in 1967 to study the polar ionosphere and measure solar and cosmic radiation.

### **France**

The first cooperative satellite with France, the FR-1, was successfully launched on a Scout vehicle on December 6 from the Western Test Range, as shown in fig. 7-2. The satellite was provided by the French National Center for Space Studies (CNES), and is measuring very low frequency (VLF) radio wave propagation. NASA and CNES have agreed in principle upon a second French satellite proposal to develop satellite and constant-level balloon techniques and instrumentation for the study of worldwide meteorological phenomena.

In October, an experiment jointly instrumented by French and NASA scientists was launched on the NASA OGO-II spacecraft. The experiment provided data on airglow and aurora at visible and ultraviolet wavelengths.

### **Germany**

NASA and the German Federal Ministry for Scientific Research signed a memorandum of understanding on July 17, providing for the launching of a German satellite to measure the spectra and flux of protons and electrons in the earth's inner radiation belt. It is planned to launch the satellite from the Western Test Range in 1968 on a Scout vehicle furnished by NASA.

### **India**

The Indian Department of Atomic Energy and NASA concluded a memorandum of understanding providing for continued cooperation between the two agencies in conducting sounding rocket experiments. Under the memorandum, 12 sounding rocket experiments will be launched from the international range at Thumba, India, to conduct aeronomy, ionospheric physics, and magnetic field studies. First launchings are planned for early 1966.

The Indian Space Commission launched 20 small meteorological rockets as part of the cooperative project with NASA which supplements the work of the International Indian Ocean Expedition (IIOE).

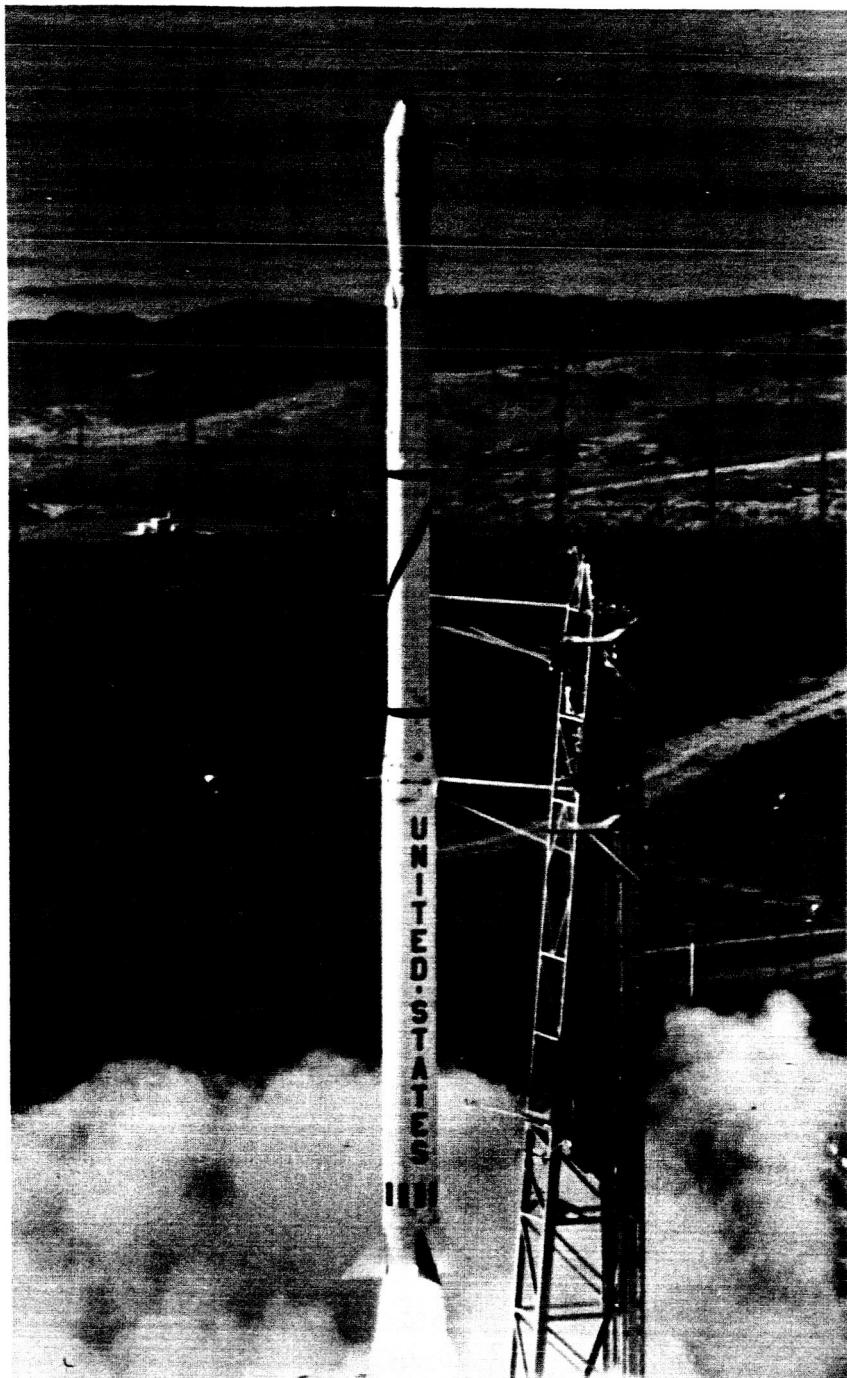


Figure 7-2. Launching of FR-1.

### **Italy**

During the period, the Italian Space Commission was continuing to assemble ground support equipment required for Phase III of the San Marco Project. This phase entails the launching of the second San Marco satellite into equatorial orbit from a platform in the Indian Ocean off the African coast in late 1966 or early 1967.

### **Netherlands**

A series of four sodium release sounding rocket experiments to measure equatorial upper atmospheric winds was conducted in September by Dutch scientists from a site near Coronie, Surinam, pursuant to an agreement with NASA. NASA provided the four Nike-Apache sounding rockets plus appropriate training and advisory services.

### **Norway**

A memorandum of understanding was signed with the Norwegian Space Research Committee providing for the launching of one Nike-Apache and six boosted-Arcas sounding rockets from the Andoya Range in Norway. The purpose of the Nike-Apache-launched experiment, scheduled for early 1966, is to study the ion composition of the D-region of the ionosphere. Two of the Arcas rockets were launched in December to support ground-based, cross-modulation studies. The remaining Arcas launchings will investigate the relationship between noctilucent clouds and electron density minima, which have been observed to occur in apparent close correlation.

An agreement was also reached providing for participation of the Norwegian Space Commission in the joint NASA/Canadian ISIS program. Beginning in early 1966, Norway will receive telemetry from the Alouette I, Alouette II, and Explorer XX Topside Sounder spacecraft at a station located at Tromso, Norway.

### **Norway/Denmark**

Despite severe weather handicaps, one Nike-Apache sounding rocket containing Danish, Norwegian, and NASA experiments was launched from the Andoya Range on November 20. This was part of a tripartite cooperative project among the Danish Ionospheric Laboratory, Norwegian Space Research Committee, and NASA to study the polar ionosphere.

### **Pakistan**

As part of a cooperative project with NASA, supplementing the International Indian Ocean Expedition (IIOE), Pakistan launched two Judi-Dart meteorological rockets from its range at Sonmiani Beach, Pakistan.

### **United Kingdom**

Two experiments designed and developed by British scientists were placed in orbit in November on the Explorer XXXI spacecraft, to make direct measurements of the ionosphere. These were the second and third British experiments to be flown on NASA satellites. Seven other British experiments have been accepted for flight by NASA.

### **Project Luster**

Experimenters from France, Germany, Israel, Sweden, and the United Kingdom provided special sampling surfaces launched on November 16 on an Aerobee sounding rocket to collect interplanetary dust and micrometeoroid particles.

### **Export of Equipment and Technology**

NASA continued to provide advice to the Departments of State and Commerce concerning the propriety of licensing the export of equipment and technology in the aerospace field.

### **Renewed Invitation for International Space Cooperation**

NASA circulated internationally the fifth edition of the document, "Opportunities for Participation in Spaceflight Investigations." This announcement sets forth specific NASA flight programs in which interested foreign scientists can participate.

### **Exchange of Scientific and Technical Information**

Under a letter agreement of May 1964, amplified in June 1965, NASA provides scientific and technical information to the ESRO/ELDO document service which, in return, furnishes information collected from its member states. Compatibility of facilities makes possible exchange of microfiche and computer tapes.

Under informal arrangements, NASA maintains a program of document exchange with 233 institutions located in 41 countries.

### **U.S.S.R.**

The exchange of conventional meteorological data between the United States and the U.S.S.R. continued over a special shared-cost communications link, pursuant to the Bilateral Space Agreement of June 8, 1962, and the implementing memorandum of understanding of November 5, 1964. These agreements provide for such exchange prior to and, on a secondary basis, during the exchange of satellite data. In New York in October, spokesmen for the Soviet side stated their expectation to have satellite meteorological data available on a continuing basis within "a few months."

On October 8, NASA and the Academy of Sciences of the U.S.S.R. signed an agreement for the preparation and publication of a joint review of research in space biology and medicine. This agreement provides for a joint editorial board and for full cooperation by both sides in the preparation of materials, the selection of authors, and the publication of their work.

### **Operations Support**

During the last half of 1965 arrangements were made for additional facilities to support NASA satellite missions in Australia, Ethiopia, the Malagasy Republic, Spain, and on Ascension Island.

#### **Australia**

An intergovernmental agreement was signed on December 7, 1965, providing for the establishment at Cooby Creek near Toowoomba of a transportable tracking and data acquisition facility to support the Applications Technological Satellite program.

#### **Canada**

On December 30, 1965, an agreement was signed between NASA and the National Research Council of Canada implementing the inter-governmental agreement of June 11, 1965, for the joint use of the Churchill Research Range of Fort Churchill, Manitoba, Canada.

#### **Ethiopia**

An exchange of letters between the American Embassy and the Haile Selassie University in October provided for the establishment of an optical scientific field station to be operated by the Smithsonian Astrophysical Observatory in conjunction with the university under a NASA grant.

#### **Malagasy Republic**

Additional land was made available by the Government of the Malagasy Republic for the expansion of the existing tracking and data acquisition station near Tananarive.

#### **Mexico**

Through the cooperation of the Mexican Government, a group of astronauts and geologists conducted a Project Apollo training exercise in the Pinacate Hills on terrain analogous to the moon's surface.

**Spain**

Arrangements were made with Spain for the expansion of the NASA tracking and data acquisition station near Madrid to accommodate a second antenna for support of the increasing lunar and planetary program workload and an antenna for Project Apollo support.

**United Kingdom**

On July 7, 1965, an intergovernmental agreement was signed, providing for the establishment of a NASA tracking facility on Ascension Island for the support of both Project Apollo and the lunar and planetary programs.

**ESRO**

In connection with plans of the European Space Research Organization (ESRO) to establish a telemetry/command station in Alaska, the House of Representatives passed legislation making ESRO eligible to receive benefits accorded to other international agencies under the terms of the International Organizations Immunities Act. Action by the Senate is pending.

**Personnel Exchanges, Education, and Training**

During the second half of 1965, over 2,500 foreign nationals from 112 locations visited NASA facilities for scientific and technical discussions or general orientation. Visitors included representatives of space research agencies in Argentina, Canada, France, Italy, Japan, Mexico, and Spain, as well as representatives of ESRO and ELDÖ. Seventy-seven members of the Washington Diplomatic Corps visited the John F. Kennedy Space Center to witness the launching of Gemini VII. The Ambassadors of Colombia, France, Norway, Sweden, Thailand, and Uganda also visited other NASA centers during the last half of 1965.

Under the NASA international university fellowship program, 25 graduate students completed their studies and 50 either entered the program or continued their studies. Seventeen countries and 20 universities participated in this program during the period. They were supported by their national space research sponsors or by the European Space Research Organization. This program is administered by the National Academy of Sciences.

Seventy-five postdoctoral and senior postdoctoral associates from 22 countries carried on research at NASA centers, including the Jet Propulsion Laboratory. This program is also administered by the National Academy of Sciences (with JPL administering its own program) and is open to U.S. nationals.

Sixty-seven technicians from Argentina, Brazil, France, India, and Italy, here at their own expense, received training in space technology at Goddard Space Flight Center and Wallops Station in connection with cooperative projects. (Fig 7-3.)

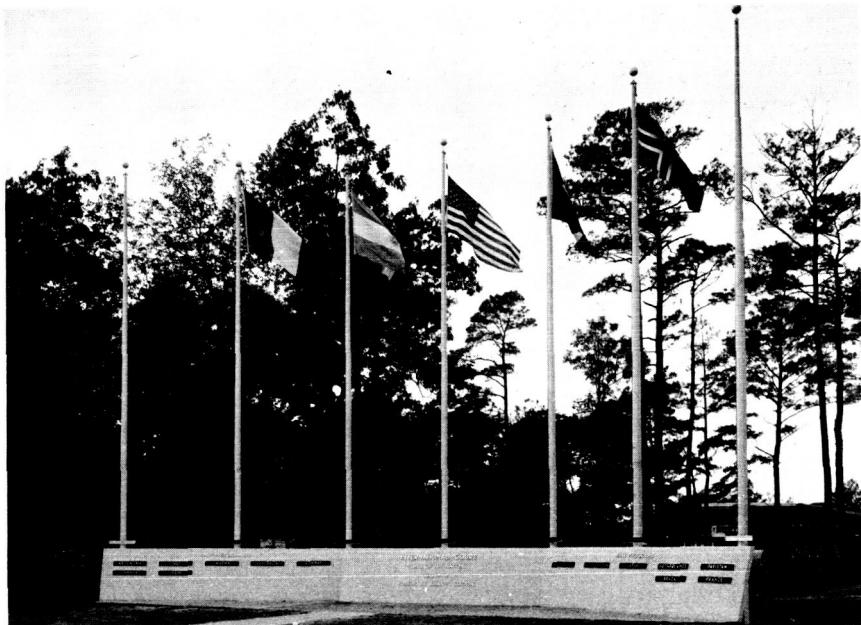


Figure 7-3. International Court at Wallops Station, where the flags of foreign countries having trainees at the station are flown daily.

Ten foreign students, sponsored by their national or regional space committees, attended a summer institute in space physics at Columbia University.



## GRANTS AND RESEARCH CONTRACTS ACTIVITIES

NASA-sponsored research at universities and nonprofit organizations is administered through the Office of Grants and Research Contracts, which develops policies and establishes procedures for receiving and evaluating all unsolicited proposals. This office also directs and administers the sustaining university program.

### Sustaining University Program

This program continued to award grants under its training, research, and research facilities components in furtherance of its purpose: to augment and complement project research and flight experiments in support of NASA's mission. It does this by helping support graduate training of scientists and engineers, by providing required research laboratories and laboratory space, and by encouraging greater university participation in the space effort.

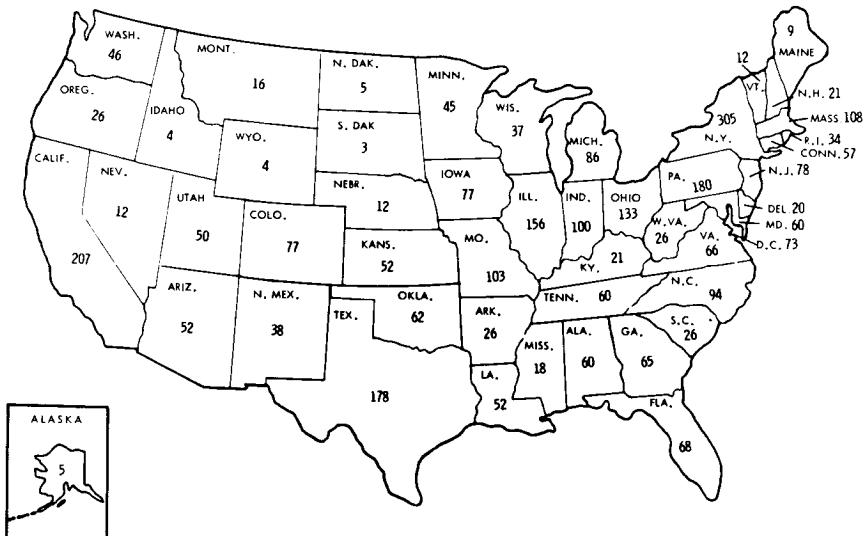
#### Training

In September, 1,275 new students began their training under this program, making a total of 3,132 NASA trainees working full time toward the doctorate at 142 universities in the 50 States and the District of Columbia. (Fig. 8-1.) The distribution of these students among disciplines is as follows:

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Discipline:	<i>Fiscal year 1965 percent</i>	<i>Fiscal year 1964 percent</i>	<i>Fiscal year 1965 percent</i>
Physical sciences-----	47.8	52.0	49.6
Engineering-----	41.5	34.8	36.1
Life sciences-----	7.8	8.5	9.8
Behavioral sciences-----	2.9	4.1	4.3
Other-----	-----	.6	.2
 <b>Total</b> -----	 100.0	 100.0	 100.0
<b>Total number of students</b> -----	<b>786</b>	<b>1,071</b>	<b>1,275</b>

In December, 152 institutions (app. R) were notified of their selection for the fiscal year 1966 program. Ten of these will be participating for the first time. Since this program began, 104 Ph. D's have been earned—56 in the physical sciences, 31 in engineering, 12 in life sciences, and 5 in other areas. Recipients of the degrees made the following career choices: University research and/or teaching—65; postdoctoral fellowships or Fulbright awards—15; employment in Government laboratories—4; employment in industry—20. All degree programs involved advanced research emphasizing space-related problems and adding significantly to the total body of space knowledge. Their contributions include, in addition to doctoral dissertations, over 125 articles, reprints, and reports on special studies prepared for publication.



**Figure 8-1.** Geographic distribution, NASA predoctoral students.

NASA's program of summer faculty fellowships brings junior faculty members in engineering or science to NASA research centers for

10 weeks of work and study (*13th Semiannual Report*, p. 148). Fifteen new fellows are selected annually at each location, and each fellow may attend a maximum of two summers. During the period of this report, 12 universities and 7 NASA field centers cooperated in offering training to just over 100 faculty members. (Fig. 8-2.) In addition to the benefits derived from the program by the trainees, the NASA laboratories obtained direct technical benefits. For example, four 1964 fellows from the Virginia Associated Research Center-Langley Research Center program were granted research contracts by the Langley center and two others were employed by Langley as lecturer-consultants.

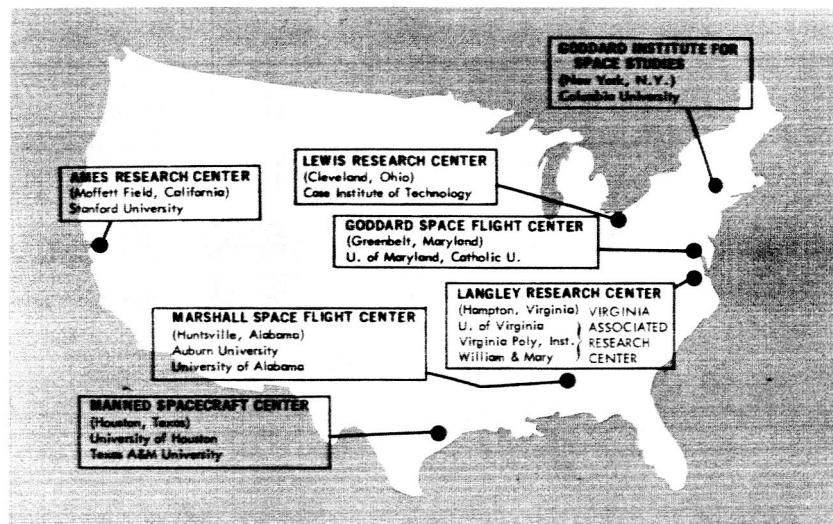


Figure 8-2. NASA Summer Faculty Fellowship Program.

The program of summer institutes for outstanding undergraduate students was continued at three locations in 1965. Nearly 140 senior undergraduates received 6 weeks of specialized training in space science and technology. After graduation, most of the participants in these institutes have gone on to graduate study in fields closely related to space subjects.

In addition, advanced training in aerospace medicine was continued at two institutions. Six physicians received specialized medical training concerned with environmental problems of man in space. The individual initiates and carries out his own research projects and also works in interdisciplinary teams with engineers, physicists, mathe-

micians, and chemists. Several physicians became acquainted with practical problems by working at the Manned Spacecraft Center.

### Research

The research element of the sustaining university program supported multidisciplinary space-related research in science and technology at 36 educational institutions throughout the country. Programs at New Mexico State University, New York University, and Pennsylvania State University were initiated during this period. The 14 research projects at New Mexico State include such diverse topics as "Geological Studies Applicable to Interpretation of Some Features of Mars," the "Influence of Light on Carotenoid Biosynthesis," and the "Economic Impact of the Apollo Project on Las Cruces." The grant also supports construction of a 24-inch telescope to be used primarily for planetary observations; it will be especially valuable for the next Mars opposition in 1967.

New York University was granted support for a broad integrated program of space-related scientific and engineering basic research. The major emphasis is on aeronautical research in fluid and solid mechanics, including investigations of boundary layer problems, radiative gas flows, fluid dynamics, heat transfer mechanisms, and of elastoplastic response of continuous systems subject to a moving load. The Pennsylvania State University grant included support for investigations of physiology of acclimation, tolerance of organisms to environmental stresses, radiation sensitivity of electron components and materials, low-noise amplifiers for radio astronomy, mechanics of irradiated bodies, hypervelocity phenomena, and kinetics of rare gases.

The other 33 institutions are:

Adelphi University	Massachusetts Institute of Technology
University of Alabama	University of Minnesota
Brown University	University of Missouri (Columbia)
University of California (Berkeley)	Montana State University
University of California (Los Angeles)	Oklahoma State University
California Institute of Technology	University of Pennsylvania
University of Denver	University of Pittsburgh
Duke University	Purdue University
University of Florida	Southern Methodist University
Georgia Institute of Technology	Texas A. & M. University
Graduate Research Center of the Southwest	University of Vermont
University of Kansas	University of Virginia
Kansas State University	Virginia Polytechnic Institute
University of Louisville	Washington University (St. Louis)
University of Maine	West Virginia University
University of Maryland	College of William and Mary
	University of Wisconsin

### Research Facilities

The following grants were awarded for the construction of research facilities to house university activities which directly support the national space program: Case Institute of Technology—\$2,226,000; University of Rochester—\$1 million; University of Florida—\$1,190,000; University of Denver—\$900,000; Stanford University—\$2,080,000. These institutions and the University of Minnesota, an earlier grantee during the year, were developing the design for their facilities with the assistance of NASA personnel.

Case Institute's Laboratory for Space Engineering and Research was being designed to support space-related training and research in fluid, plasma, and thermal dynamics; nuclear and chemical engineering; solid state electronics; circuits; and fields. When completed the new multidisciplinary building will also provide additional opportunities for graduate level training of NASA employees from the Lewis Research Center. The University of Rochester presented plans to build a space sciences laboratory to consolidate and enlarge its NASA-sponsored ground-based research and flight experiments. Faculty and graduate students from all science and engineering departments and the medical school will share equipment and experience in an academic atmosphere focused on the phenomena of space. The Space Sciences Building at the University of Florida will contain NASA-supported research groups from throughout the university. Laboratories were being planned for astrophysicists, astronomers, engineers, biologists, and human performance physiologists and psychiatrists. A computer center to be included will serve all occupants. The University of Denver was completing development of plans for a laboratory building for space-related research and graduate training in cosmic rays, molecular collisions, defect states, ceramics and intermetallics, ultra-high vacuum environments, thermophysical properties, hypervelocity aeroballistics, high-altitude environments, and dynamic deformation. The Space Engineering Laboratory at Stanford University was being planned to accommodate large and varied programs in aerospace engineering with facilities for fabricating and testing components and systems for satellite and laboratory experiments. In addition, NASA scientists and engineers from the Ames Research Center will have increased opportunities for advanced training in the new building.

Six NASA-supported facilities were completed in this period increasing the total number in use to 17. The NASA-funded portion of

the physics and astronomy building at the University of Iowa was completed, enabling research groups to consolidate their activities in adequately equipped facilities. (Fig. 8-3.) Spacecraft will be developed and tested here before flight, and after launch, data from the satellites will be received and analyzed. The National Science Foundation and the State provided support for other parts of the building. The Laboratory for Atmospheric and Space Physics at the University of Colorado was dedicated and occupied. (Fig. 8-4.) It contains facilities for the design, development, fabrication, and testing of satellite and rocket instrumentation to measure solar radiation. The laboratory also provides equipment for supporting research and the analysis of data received from flight experiments. The facilities completed at the University of California, Los Angeles, contain laboratories for space biology, space physics, electrical engineering, and inorganic chemistry. (Fig. 8-5.) There are also data-reduction laboratories, environmental testing areas, experimental animal facilities, and shops to support the main laboratories. The university participates in 10 NASA rocket and satellite experiments and wide-ranging basic laboratory research.

At Washington University, St. Louis, Mo., the wing of the physics building jointly funded by NASA, the National Science Foundation, and the university was completed and became available for graduate research and training in physics. The NASA-funded portion is used specifically for NASA-sponsored electronic investigations of primary cosmic radiation. The Polytechnic Institute of Brooklyn moved its large wind tunnels and supporting equipment into a new building specially designed for research and training in supersonic and hypersonic flow. The building (fig. 8-6) is at the Farmingdale, Long Island, graduate campus. The renovations and additions to the Human Centrifuge Facilities at the University of Southern California were completed and dedicated. (Fig. 8-7.) University investigators began basic research with humans and large animals in high-acceleration environments, and NASA contractors are using the equipment for applied research directly supporting the Apollo program. The Laboratory for Space Sciences at the University of Chicago (*12th Semiannual Report*, p. 148) and the Space Research and Coordination Center at the University of Pittsburgh (*13th Semiannual Report*, p. 151) were also dedicated.



Figure 8-3. University of Iowa facility.

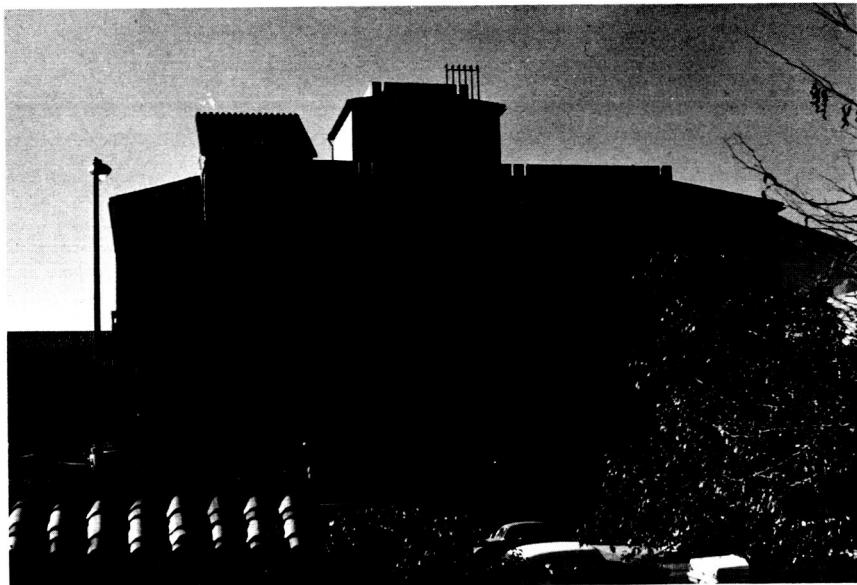


Figure 8-4. The University of Colorado laboratory building.



Figure 8-5. Slichter Hall, University of California, Los Angeles.

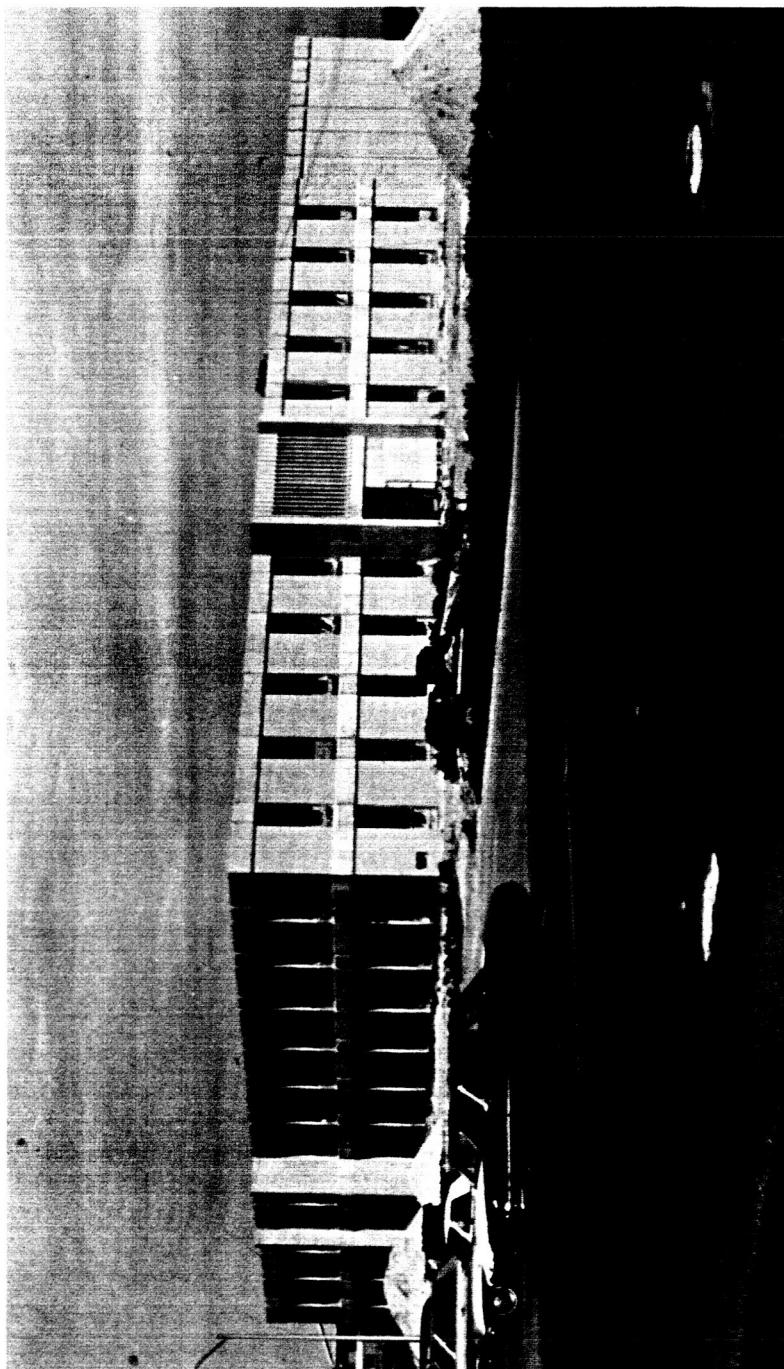


Figure B-6. Preston R. Bassett Research Laboratory, Polytechnic Institute of Brooklyn.

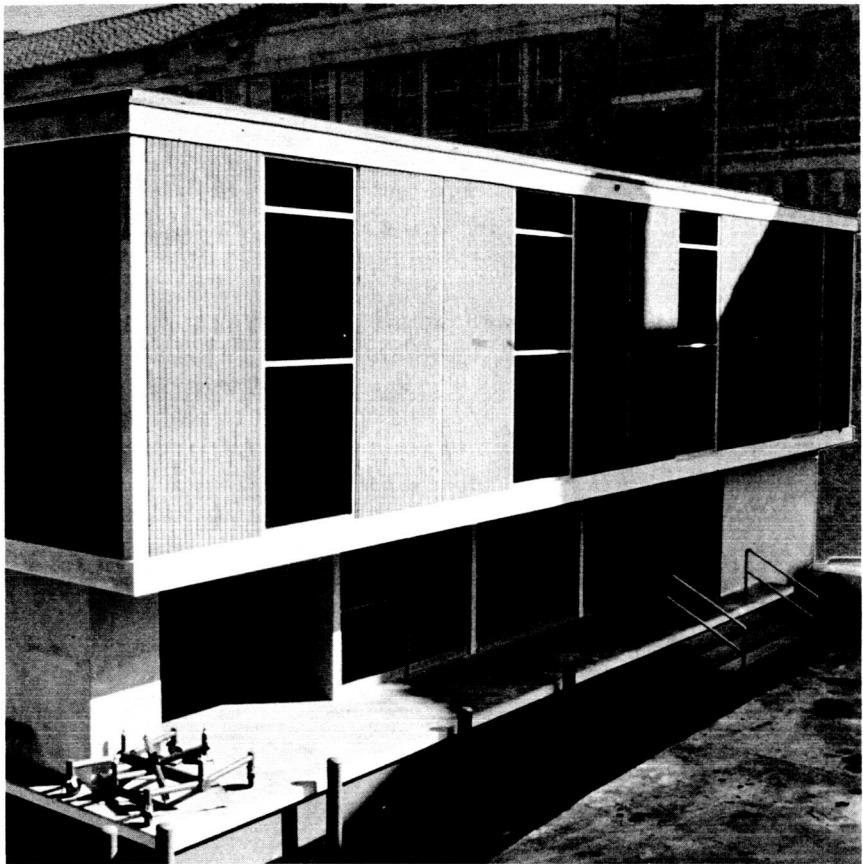


Figure 8-7. Human Centrifuge Facilities, University of Southern California.

Ten additional projects were under construction as Cornell and Illinois initiated work during this period. The status of all facilities under construction is shown below.

Institution:	Topic	Percent complete (Dec. 31, 65)
Massachusetts Institute of Technology.	Space sciences-----	15
University of Wisconsin-----	Theoretical chemistry-----	15
Texas A. & M. University-----	Space sciences-----	25
University of Maryland-----	do-----	45
Cornell University-----	do-----	10
Rice University-----	do-----	30
New York University-----	Aeronautics-----	20
Georgia Institute of Technology.	Space sciences-----	50
University of Arizona-----	do-----	30
University of Illinois-----	do-----	5

**Resident Research Associate Program**

The National Academy of Sciences administers a program for NASA which is designed to allow postdoctoral and senior postdoctoral investigators to carry on advanced research at NASA field centers. Participants carried on research in fields such as astrophysics, air-glow emission, high-energy physics, geomagnetism, instrumentation for direct atmospheric measurements, applied mathematics, electron microscopy, comparative biochemistry, hypersonic aerodynamics, plasma flow, materials, and meteorites. Articles resulting from the studies were submitted to or were published in such professional publications as the *Astrophysical Journal*, *Review of Modern Physics*, *Journal of Chemical Physics*, *Journal of Neurology*, or as *NASA Technical Notes*. The 88 scientists conducting research under this program were distributed among NASA centers as follows:

Goddard Space Flight Center.....	52
Institute for Space Studies, New York, N.Y.....	14
Greenbelt, Md.....	38
Ames Research Center, Moffett Field, Calif.....	30
Langley Research Center, Langley, Va.....	2
Marshall Space Flight Center, Huntsville, Ala.....	4
	88

**Management of Grants and Research Contracts**

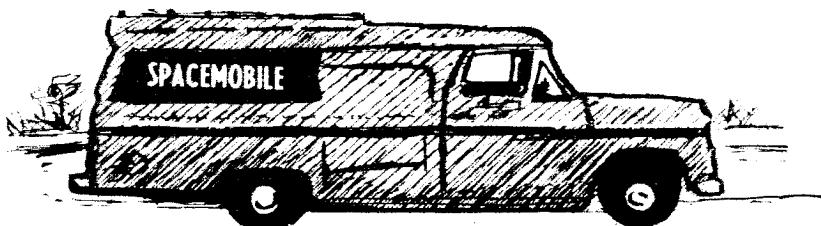
Further improvements were made in the management system for grants and research contracts. Automatic data-processing reporting systems were refined to provide summary obligation data by program office and unique project levels. Progress was made in developing the system for manpower and expenditure reporting by institutions and in refining the automatic data processing of such data. In addition, instructions for preparing the University and Nonprofit Institution Financial Report were clarified and amplified.

The Letter of Credit system (*12th Semiannual Report*, p. 154) for providing funds to grantees was in operation at 26 universities. A NASA Training Grant Financial Report form providing financial information on stipends, student allowances, and university allowances was put into use at 131 universities. It covers the period beginning September 1 and ending August 31, and must be submitted annually. Another NASA form, Research Facilities Grant Financial Report, was approved by the Bureau of the Budget. It will provide estimated costs, budget, and expenditure data for each facilities grant and will be required for the period ending each June 30 and upon completion of the project.

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During this period the Office of Grants and Research Contracts received 1,886 proposals from universities, nonprofit institutions, private industries, and other sources. This was an increase of approximately 15 percent over the same period of the previous year. Procurement actions received from various NASA offices and field centers totaled \$81.2 million and obligations processed totaled \$38.5 million.

# 9 INFORMATION AND EDUCATIONAL PROGRAMS



Whether the requestor be a scientist, engineer, teacher, industrialist, student, or an interested member of the general public, the Agency strives to meet his request for general, scientific, or technical information. During the last 6 months of 1965, the requests for information and educational materials of all kinds continued high.

The Scientific and Technical Division (Office of Technology Utilization) and the Educational Programs Division (Office of Public Affairs) share the responsibility for fulfilling these needs.

Efforts to effect accurate, straightforward, swift and economical dissemination continued during this period.

Reductions in costs in an effort to refine dissemination practices are shown by these examples.

Substantial savings realized in the exhibits program were shown when over 8.5 million viewers saw NASA exhibits at only about 3 cents a viewer. An arrangement with another Government agency to use its composing equipment resulted in producing compact, more readable indexes for NASA's *Scientific and Technical Aerospace Reports* at reduced printing charges. And, as another economy measure, a central service was set up to provide engineers with a single checkpoint on the origin and availability of aerospace research and development specifications.

## Educational Programs and Services

Studying the impact of space science on school curricula and searching for ways to help educators solve this growing problem, NASA co-operated with the University of South Florida in conducting a conference of educational administrators and teachers from Georgia, Florida, Puerto Rico, and the Virgin Islands. The Agency also worked with the Departments of Education of Massachusetts and Texas in setting up programs to develop aerospace curriculum-resource guides for teachers.

To meet instructional needs of schools, colleges, and universities in space science and technology, the Agency helped develop educational materials at all levels. For example, *NASA Facts* (app. M) were published and distributed, and "educational briefs" were developed and published at the Manned Spacecraft Center and at Goddard Space Flight Center. Curriculum syllabi in space-related aspects of the physical sciences were being produced at Columbia University and other syllabi in space-related aspects of the biological sciences were being prepared at the University of California (Berkeley).

NASA assisted over 275 colleges and universities in planning space science courses, arranged summer workshops for more than 14,000 teachers, and helped increase public understanding of the space program through adult education. It also began a program in cooperation with Howard University (Washington, D.C.), to conduct lectures for culturally deprived groups in an urban area (New York City), a suburban area (Jacksonville, Fla.), and a rural area (Cheneyville, La.). In supporting youth programs, the Agency assisted the Boy Scouts of America to develop a merit badge in space exploration. The first badge was awarded in a ceremony at the Manned Spacecraft Center in November.

### Spacemobiles

Twenty-seven of NASA's spacemobile lecture-demonstration teams spoke on space science and exploration before over 1 million school children, teachers, and civic groups during this report period. Also spacemobile lecturers made radio and television presentations to an estimated audience of over 5 million. During the summer teacher workshops, seminars, and extended programs at planetariums were emphasized. In addition, special programs for students in culturally deprived areas were carried on in Philadelphia, Pa., Pasadena, Calif., and Boston, Mass.

### Educational Publications and Films

NASA released seven new publications, issued updated editions of several previously published, and produced five new motion pictures, all described in appendix M. Over 32,000 requests for publications and 3,100 requests for motion pictures were received from teachers, students, professionals, and the general public. Motion picture film cataloged and stored in NASA's depository reached 7 million feet, and 84,000 feet of film was made available to producers of educational and documentary movies and telecasts.

### Educational Television and Radio

During the last 6 months of 1965 NASA sought to provide information on space research and development to an ever-increasing audience of TV viewers. (The report period saw the number of television stations exceed 700 reaching into 53 million homes.)

The Agency continued to produce and distribute its monthly 5-minute program "Aeronautics and Space Report." Topics included the Mariner-Mars mission and the Gemini VI and VII flights. Also the series of six half-hour educational television documentaries, "Space: Man's Great Adventure," emphasizing the "human element" in space research and development, was carried by commercial stations. In addition, motion pictures not designed primarily for television were supplied TV stations. For example, a film of the Gemini IV flight was telecast by 169 stations. It is estimated that more than 77 million saw these programs in 1965 (not including viewers of "Aeronautics and Space Report").

Production began on a new group of 13 half-hour programs in the "Science Reporter" series which focus on major NASA scientific and technical activities. These will be released to educational and commercial television stations in the spring of 1966.

NASA also provided technical guidance and information, and loaned visual materials to individual stations, networks, and producers. On several occasions assistance was given network programs with large audiences. In addition, assistance was provided to the Canadian Broadcasting Corp. and the British Broadcasting Corp.

Reflecting the resurgent interest in radio for communicating news and information, the Agency's series of 13 half-hour programs on bioastronautics ("Their Other World") received an overwhelming response. "Space Story," a weekly 5-minute program highlighting current developments, was broadcast by commercial stations.

## Exhibits

NASA's exhibits were displayed at 283 events during the report period. The Gemini IV spacecraft flown by Astronauts McDivitt and White in June was on display at the New York World's Fair Space Park. The Space Park, which closed October 17, was visited by 2.5 million people during the 1965 season.

In the fall NASA took an exhibit on a tour of 7 State fairs which was seen by 8,360,000 at the very low cost to the Agency of 2.7 cents a viewer. Another exhibit tour in Hawaii drew an audience of 236,064 at only 3.75 cents a viewer.

For the first time NASA accepted an invitation from a city of less than 50,000 people to develop a large space exposition. This "Virginia-Carolina Space Exposition" at Danville, Va., in November was seen by 80,193, including students from 131 schools in Virginia and North Carolina. (Fig. 9-1.)

The Gemini IV spacecraft was loaned to the U.S. Information Agency for special tours in Brazil and Mexico, and the inventory of educational exhibits was being revised and updated to cover the latest manned and unmanned missions as the pace of the manned space flight program accelerated.

## Scientific and Technical Information

NASA continued to improve its information-processing methods for greater speed and economy. It also devised additional services including an improved technique for publishing indexes in cooperation with another Government agency and expanded information services for aerospace engineers.

### Processing of Information

Much of the data needed to support NASA research and development activities is produced by other agencies. Consequently, cooperative arrangements with them for receiving and disseminating the data in immediately usable form do much to assure efficient processing. Compatible procedures for cataloging new information, the exchange of worksheets and magnetic tapes prepared for information storage and retrieval, and standardized procedures to make information available in microform are examples of the arrangements to prevent duplication of effort, reduce unit cost, and contribute to the timeliness of the service. NASA also arranged to use graphic art composing equipment developed by the National Library of Medicine to index the *Scientific and Technical Aerospace Reports (STAR)*. The index was previously prepared by computer printout. The results of the new method are



Figure 9-1. Virginia-Carolina Space Exposition, Danville, Va.

high-speed production of more readable pages, more lines per page, a published index one-third as large as the one produced by the computer-printer, and a more convenient information tool produced at lower cost.

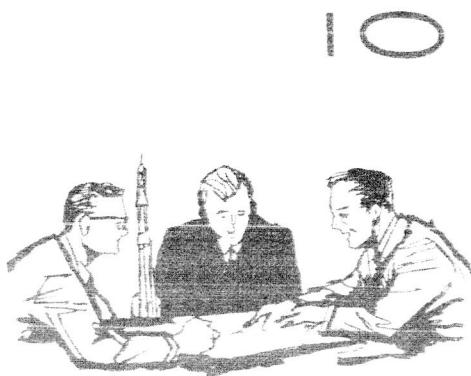
### Information Service for Engineers

In the first phase of an enlarged scientific and technical information program for engineers, NASA set up a central service to provide information on research and development specifications originating in or outside the Agency. Thus, engineers will have available a single check-point to answer questions on the origin and availability of such material. In its next phase the program is expected to offer coordinated services for locating component parts life data, equipment test reports, and testing procedures.

### Technical Publications

A selected list of NASA's scientific and technical publications is given in appendix N. Two of these—unusual in their scope and widespread utility—were released during this period:

- A *Dictionary of Technical Terms for Aerospace Use*—provides authoritative definitions of over 6,000 terms commonly found in the literature of space exploration, and
- A *Sourcebook on the Space Sciences*—offers a comprehensive account of the principles and applications of space science for readers with an elementary knowledge of the conventional sciences.



# PERSONNEL, MANAGEMENT, PROCUREMENT, AND SUPPORT FUNCTIONS

Efforts continued during the period to improve the efficiency of the Agency's personnel, management, procurement, and other nontechnical activities. The objective of these efforts was to assure that all missions would receive the required support, within the framework of sound government practices. Endeavors within the personnel field were aimed at making more effective use of on-board employees and increasing the productivity of the work force. Further improvements were made in the structure and functional alignment of the Agency's organization, positive actions were employed to enhance both the financial management and the procurement practices, and such areas as technology utilization and NASA relationships with other Government agencies were further emphasized.

## Personnel

In its personnel field, the Agency placed increased stress on employee-management cooperation, on its employee training program, and on equal employment opportunities for all qualified persons. Certain personnel changes affected a number of key positions, and deserving individuals both inside and outside the Agency received well-deserved recognition for their contributions to the space program.

### Employee-Management Cooperation

There has been active participation in the Government-wide program for employee-management cooperation in the Federal service (Executive Order 10988). The Lewis Research Center and Lodge 2182, American Federation of Government Employees (AFL-CIO), concluded negotiations on Supplement No. 1 to their basic collective agreement, and it was approved by the NASA Administrator. The Marshall Space Flight Center and Lodge 1858, American Federation of

Government Employees (AFL-CIO), concluded negotiations, and their collective agreement was undergoing review for approval by the NASA Administrator.

A NASA policy directive was issued, providing for union recognition of nonappropriated fund activity employees (cafeteria workers). Such employees are not covered by either the National Labor Relations Act, or Executive Order 10988. Also, formal recognition at the national level was granted to the national office of the American Federation of Government Employees.

### **Training Activities**

Continued emphasis was given to the established specially designed seminars for management improvement and operations. During this period, 951 persons participated in courses in procurement management, incentive contracting, contract cost management, and PERT courses.

In addition, NASA developed a 5-day course in contract administration to provide procurement officers—including those assigned to the Defense Contract Administration Services Regions—with a comprehensive familiarization of the new NASA contract administration plan: How it works, the tools it provides, and its impact on program and project management. The course also interweaves a familiarization of the DOD Contract Administration Services organization (DCASR) and its operation throughout the country.

Increased emphasis was given to course offerings in communications skills. Two new courses, utilizing programmed instruction techniques, were added. A course in clear writing and report construction was specially developed for NASA employees, and a recently developed course in effective listening was offered throughout the Agency.

### **Equal Employment Opportunity**

During the period, NASA installations continued to demonstrate positive efforts to implement the equal opportunity program for Federal employees. During the summer of 1965 a large percentage of Youth Opportunity Campaign employees were minority group members. At one installation nearly 50 percent were Negro.

Several installations were doing a highly creditable job of career counseling for minority groups. In one geographic area, this is a continuing program, in part accomplished through informal discussions held at settlement houses and youth centers where Caucasians and Negroes in responsible positions address the groups.

Continuing activities of the installations included: (1) Intensive recruiting at predominantly Negro high schools and colleges; (2)

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selecting Negro teachers and students to participate in NASA's summer employment program; (3) conducting career motivation programs at junior and senior high schools in "disadvantaged" neighborhoods and predominantly Negro colleges; and (4) selecting Negroes to participate in co-op training programs.

### **Status of Women**

The headquarters coordinator for the status of women program visited several installations as principal speaker at luncheon meetings of key women employees. The coordinator also addressed two outside groups: The girls at a local high school to outline opportunities for women in the space age; and the Women's Personnel Club of Boston, a group which had expressed interest in the Federal program for the status of women.

The total number of women occupying positions at GS-12 and above is 174. This represents an increase of 39 since initial report of women in these grade levels was required in December 1963.

In close cooperation with the status of women coordinator at each NASA installation, continuous stress was placed on providing training and career development opportunities to all qualified female employees, including those in scientific, technological, and administrative areas.

### **Status of Personnel Force**

NASA decreased its staff from 34,049 to 33,355 during the period from June 30, 1965, to December 31, 1965. Temporary summer employees who left the Agency in September accounted for this decrease. The distribution by installation was:

Organization:	June 30, 1965	Dec. 31, 1965
Ames Research Center-----	2,270	2,236
Electronics Research Center-----	250	340
Flight Research Center-----	669	629
Goddard Space Flight Center-----	3,774	3,560
John F. Kennedy Space Center, NASA-----	2,464	2,486
Langley Research Center-----	4,371	4,263
Lewis Research Center-----	4,897	4,834
George C. Marshall Space Flight Center-----	7,719	7,503
Manned Spacecraft Center-----	4,413	4,391
Pacific Launch Operations Office-----	21	0
Wallop Station-----	554	526
Western Operations Office-----	377	343
Headquarters-----	2,135	2,112
(AEC/NASA) Space Nuclear Propulsion Office-----	116	112
JPL resident office-----	19	20
Total-----	34,049	33,355

### Key Executive Personnel Changes

NASA appointed five persons to key positions within the Agency and reassigned seven others. Two officials, both outstanding space leaders, passed away, two retired, and two resigned.

*Key Appointments.*—On September 7, 1965, Mr. Willis H. Shapley was appointed as Associate Deputy Administrator, NASA. He came from the Bureau of the Budget where he had served as Deputy Chief of the Military Division and as Assistant to the Director for Space Coordination. Mr. Shapley joined the Bureau in 1942.

James C. Elms was appointed as Deputy Associate Administrator for Manned Space Flight on August 27, 1965. He came from the Space and Information Systems Division, Raytheon Corp., Lexington, Mass., where he had served as vice president and general manager. Earlier (February 1963 to March 1964) Mr. Elms had served as Deputy Director of the NASA Manned Spacecraft Center. He had previously filled various executive positions with the Aeronautics Division of the Ford Motor Co., the Crosley Division of the AVCO Corp., the Martin Co., and the North American Aviation Corp.

On October 4, 1965, Dr. Mac C. Adams was appointed as Associate Administrator for Advanced Research and Technology. Dr. Adams came from the position of vice president and assistant general manager for space systems, AVCO Corp., Wilmington, Mass. He had been associated with AVCO since 1955.

On November 19, 1965, Robert E. King was appointed Director of Labor Relations in the Office of Industry Affairs, and reported for duty January 5, 1966. Previously, Mr. King had served as manager of labor relations for General Dynamics/Convair.

*Reassignments.*—On December 21, 1965, Dr. Robert C. Seamans, Jr., was appointed as Deputy Administrator, succeeding Dr. Hugh L. Dryden. Dr. Seamans had served as Associate Administrator of NASA from September 1, 1960, when he joined the Agency, coming from the Radio Corp. of America where he had been chief engineer, missile electronics and controls division.

Dr. Raymond L. Bisplinghoff was appointed as Special Assistant to the Administrator on October 4, 1965. From August 1, 1962, he had served as Director of and subsequently Associate Administrator for Advanced Research and Technology. Prior to joining the NASA staff, Dr. Bisplinghoff had been professor of aeronautical engineering and deputy head, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology.

On October 16, 1965, H. Julian Allen was appointed Director of the NASA Ames Research Center, succeeding Dr. Smith J. DeFrance who retired October 15. Mr. Allen had served with NASA and the

former NACA from 1936, and from November 1959 had been an Assistant Director of the Ames Center.

On July 23, 1965, John W. Townsend, Jr., was appointed Deputy Director of the NASA Goddard Space Flight Center, Greenbelt, Md. Dr. Townsend had been Assistant Director of the Center for space sciences and satellite applications since April 1959. He came to NASA from the U.S. Naval Research Laboratory with which he had been associated from 1949 and where he had headed research in the field of upper atmospheric physics.

Frank A. Bogart (lieutenant general, USAF, retired) was appointed Deputy Associate Administrator for manned space Flight (Management) on September 1, 1965. General Bogart joined NASA in December 1964 as a special assistant to the Associate Administrator for Manned Space Flight, and from February 1965 had been Director of Manned Space Flight Management Operations.

On December 19, 1965, Bernard Moritz was appointed Deputy Assistant Administrator for Industry Affairs (the present title, as changed January 2, 1966). He had served as Assistant General Counsel, NASA, from May 1961.

*Terminations.*—Dr. Hugh L. Dryden, Deputy Administrator of NASA, and the Director of the former National Advisory Committee for Aeronautics, passed away on December 2, 1965. A special statement on Dr. Dryden's career and contributions will be found on page 209 of this report.

On December 12, 1965, Dr. W. Randolph Lovelace II, was killed in an airplane crash in the Colorado Rockies. Dr. Lovelace had served as Director of Space Medicine in the NASA Office of Manned Space Flight from April 21, 1964.

Dr. Smith J. DeFrance retired from the position of Director, NASA Ames Research Center, Moffett Field, Calif., on October 15, 1965. He had served in this capacity from the time the (former NACA) Ames Aeronautical Laboratory was established in 1940. He had previously been head of the flight research division at the Langley Laboratory (1925-40), a position to which he was appointed 3 years after he joined the former National Advisory Committee for Aeronautics.

On October 30, 1965, Dr. Harry J. Goett retired from the position of Special Assistant to the Administrator. From September 1959 to July 1965 he had been the first director of the NASA Goddard Space Flight Center, Greenbelt, Md. He came to this position from the NASA Ames Research Center where he had been Chief of the Full-Scale and Flight Research Division. Dr. Goett joined the staff of the (NACA) Langley Laboratory in 1936, and transferred to the (then) new Ames Center in 1940.

On December 4, 1965, Clyde Bothmer resigned from the position of Director, NASA Office of Industry Affairs (Pentagon), a position he had occupied since February 14, 1965. Mr. Bothmer had previously served in several executive capacities within the Office of Manned Space Flight.

David S. Gabriel resigned (December 14, 1965) from the position of Project Manager, Centaur, at the NASA Lewis Research Center, Cleveland, Ohio. Mr. Gabriel had served with NASA and former NACA at Lewis from 1943. From 1953 he had in turn been Assistant Chief of this project, Chief of the former Engine Research Division, Chief, Propulsion Systems Division, and Chief of the Nuclear Systems Division. He had served as the Centaur Project Manager from February 1963.

#### NASA Awards and Honors

Special honorary recognition was given to individuals and groups for their contributions to the Nation's space program.

*NASA Distinguished Service Medal.*—One award was granted:

*William H. Pickering, JPL.*—For his long and distinguished national and international leadership in the fields of science and technology and for his outstanding performance as Director of the Jet Propulsion Laboratory in directing the team of scientists and engineers responsible for the success of Mariner II, Mariner IV, and Rangers VII, VIII, and IX. The scientific achievements from these missions have placed the United States in the forefront of lunar and planetary exploration.

*NASA Outstanding Leadership Medal.*—Four awards were presented:

*Oran W. Nicks, Headquarters.*—For organizing and leading a team comprised of university, Government, and industry scientists and engineers who so successfully planned and executed the Ranger and Mariner projects on a broad program of lunar planetary exploration. The success of these outstanding efforts in space exploration has given new knowledge about the solar system and has provided a technological base for further exploration of the moon and planets.

*Bruce T. Lundin, Lewis Research Center.*—For his outstanding contributions in planning, organizing and executing highly successful research and development programs at the Lewis Research Center. His inspiring leadership has resulted in significant and timely advances in aerospace technology and successes in the NASA Space Flight Program.

*Charles W. Mathews, Manned Spacecraft Center.*—For his outstanding contribution in directing the Gemini program. His ability

to solve complex technological and managerial problems resulted in significant advances in this Nation's manned space flight program, including the first maneuvers by a manned spacecraft, the first two-man long-duration flight, and the first self-propelled flight by man outside a spacecraft.

*Smith J. DeFrance, Ames Research Center.*—For his outstanding contributions in directing research for the advancement of aeronautics, from subsonic to hypersonic, and in varied scientific disciplines in support of space exploration. His achievements encompassing four decades have contributed significantly to the security and technological progress of the United States.

*NASA Exceptional Scientific Achievement.*—Six medals were presented:

*Jack N. James, JPL.*—For outstanding accomplishment in the design, development, and flight operation of Mariner II and Mariner IV. Mariner II made the world's first direct measurements of the environment of Venus and represented the beginning of a long-range program of planetary exploration. Mariner IV, in accomplishing the world's first successful space flight to the vicinity of Mars, obtained the first closeup photographs of that planet and provided major new scientific information about the nature of the Mars' surface and environment.

*Dan Schneiderman, JPL.*—For significant contributions to the success of the Mariner IV flight to Mars. As spacecraft systems manager and later project manager he effectively coordinated the scientific and engineering efforts which led to new information on interplanetary space, provided closeup pictures of Mars, and yielded important scientific data on its atmosphere.

*Eberhardt Rechtin, JPL.*—For his outstanding contributions in the design, development, and operation of NASA's Deep Space Network for tracking, communication with, and control of the U.S. lunar and planetary exploration spacecraft. These achievements, including the Mariner and Ranger flights, have contributed to the leadership role of the United States in the technology of deep space telecommunications.

*Leslie H. Meredith, Goddard Space Flight Center.*—For assembling and directing an outstanding group of space scientists who have significantly advanced our Nation's knowledge and understanding of the space environment, and for originating mission concepts and scientific payloads on Explorer and Observatory spacecraft.

*William Nordberg, Goddard Space Flight Center.*—For the development of a highly intricate infrared image system which has contributed greatly to man's knowledge of the earth's surface and atmospheric

surroundings, thereby enhancing the interpretation of meteorological and geodetic phenomena.

*H. Julian Allen, Ames Research Center.*—For his contributions and leadership in solving key research problems in the design of supersonic airplanes, missiles, and spacecraft, especially the thermal protection problems at hypervelocities, culminating in applying meteor phenomena as a unique tool for examining the heating problems.

*NASA Group Achievement Award.*—Nine Group Achievement Awards were presented:

*The Scout Project Office, Langley Research Center.*—For sustained cooperative effort which led to a spectacular series of Scout launch vehicle successes, and for individual excellence in the performance of duties which contributed immeasurably to the Scout reliability improvement program which produced a versatile launch vehicle of better than 90 percent reliability.

*Launch Support Equipment Engineering Division, Kennedy Space Center.*—For significant achievements in the design and development of launch support equipment for the Saturn I, a launch vehicle of unprecedented size and complexity which completed a successful 10-launch program.

*MSC—Florida Operations, Team, Kennedy Space Center.*—For outstanding competence in the design and development of acceptance checkout equipment which provided a faster and more flexible means for the total preflight testing of the Apollo spacecraft.

*Agena Project Group, Lewis Research Center.*—For their outstanding technical and management achievements and their scientific and engineering contributions to the Atlas-Agena and Thor-Agena projects which resulted in a series of outstanding successful spacecraft launches. Their dedicated team effort has contributed significantly to NASA goals in the scientific exploration of space and in the application of space technology to the uses of mankind.

*The Radar Tracking Group, Wallops Station.*—For superior technical and operational leadership and outstanding results obtained by the Mobile Launch Facility during Expedition No. 1 off the west coast of South America.

*The Vehicle Assembly and Launch Crew, Wallops Station.*—For superior assembly and operation techniques in assembling and launching scientific experiments aboard the Mobile Launch Facility during Expedition No. 1 off the west coast of South America.

*The Management and Operational Group, Wallops Station.*—For outstanding competence in planning and managing the development and coordinating operations for the Mobile Launch Facility during Expedition No. 1 off the west coast of South America.

*The Flight Services Group, Wallops Station.*—For outstanding competence demonstrated in operating and maintaining a variety of electronic equipment aboard the Mobile Launch Facility during Expedition No. 1 off the west coast of South America.

*The Meteorological Group, U.S. Weather Bureau, Wallops Station.*—For outstanding achievement in obtaining meteorological data never before obtained in the area of the Southeast Pacific. This information was obtained during Expedition No. 1 of the Mobile Launch Facility.

*Exceptional Service Medal.*—Eleven Exceptional Service Awards were presented:

*Edward H. White, II, Manned Spacecraft Center.*—For outstanding contributions to space flight and engineering. His performance, as pilot during the 4-day Gemini IV mission and as the first man to engage in self-propelled extravehicular activity significantly extended our knowledge of the space environment and man's capabilities in space flight.

*James A. McDivitt, Manned Spacecraft Center.*—For outstanding contributions to space flight and engineering. His performance as command pilot during the 4-day Gemini IV mission, including his control of the spacecraft during this Nation's first demonstration of extravehicular activity, significantly extended our knowledge of the space environment and man's capabilities in space flight.

*George L. Simpson, Jr., Headquarters.*—For his important contributions in the areas of public affairs, policy planning, and technology utilization; and for his understanding and wisdom in expanding and strengthening NASA's programs which emphasize the role of the university as a trusted source of information in a time of vast and rapid scientific technological change.

*Gerald D. O'Brien, Headquarters.*—In recognition of his exceptional and dedicated service in organizing and directing the patent program since the establishment of NASA and his significant contribution to patent law.

*Charles A. Berry, Manned Spacecraft Center.*—For his outstanding contributions to space medicine through his direction of and personal participation in the medical planning and control of the Gemini manned space flights. His work as the senior medical officer in the 8-day Gemini V mission has extended greatly our knowledge of man's capabilities in space.

*Leroy Gordon Cooper, Jr., Manned Spacecraft Center.*—For outstanding contributions to technology of manned space flight. His performance as command pilot during the 8-day Gemini V mission significantly extended our understanding of the capabilities of man

and equipment under prolonged exposure to space flight environment. His participation in real-time flight planning added greatly to the knowledge required for future long-duration manned space flights.

*Charles Conrad, Jr., Manned Spacecraft Center.*—For outstanding contributions to technology of manned space flight. His performance as pilot during the 8-day Gemini V mission significantly extended our understanding of the space flight environment. His participation in real-time flight planning added greatly to the knowledge required for future long-duration manned space flights.

*William E. Lilly, Headquarters.*—For outstanding achievement in establishing effective management systems for the budgeting and utilization of financial resources for the total manned space flight effort; for research and development and administrative operations, and for the overall management of the manned space flight facilities program involving the planning and construction of complex technical and support facilities at 11 locations.

*Seymour C. Himmel, Lewis Research Center.*—For exceptional contributions in the Agena vehicle launch programs and for his sound engineering judgment which produced an outstanding record of successful launches.

*John R. Casani, JPL.*—For significant engineering achievements related to the Mariner mission to Mars. As Mariner project engineer and later spacecraft systems manager, his contributions to the design and development of the Mariner IV spacecraft helped provide man's first closeup view of another planet and increased our knowledge of the interplanetary space environment.

*Osmond J. Ritland, Headquarters.*—For his distinguished service as a leader in the development and operation of the Nation's space programs. He led development of the technology for man-rating the Mercury-Atlas and Gemini-Titan launch vehicles. He also provided an unprecedented example of cooperation between the Air Force and the National Aeronautics and Space Administration in the attainment of man's capabilities in space flight.

*NASA Certificate of Appreciation.*—Two Certificates of Appreciation Awards were presented:

*Albert A. Vollmecke, Headquarters.*—For his outstanding contributions in aeronautical engineering, particularly for his advice and counsel on structural and materials research programs for the past 24 years as a member of NACA and NASA research advisory committees.

*Ernest L. Struttmann, Headquarters.*—For his 37 years of faithful service to the U.S. Government, and in particular his substantial contribution to the improvement of financial management in the National Aeronautics and Space Administration.

### **Inventions and Contributions Board**

The Space Act (1958) provided for the establishment of the Inventions and Contributions Board. Among the Board's functions is the review of petitions from NASA contractors for waiver of rights to inventions made under NASA contracts. It then recommends to the Administrator the granting, denial, or other action on such petitions.

In addition, the Board evaluates scientific and technical contributions made by NASA employees, contractors, or other sources and recommends to the Administrator monetary awards for those found to be of significant value in the space or aeronautical program. It also evaluates inventions made by NASA employees and, on its own cognizance, may make monetary awards. It conducts hearings on petitions for waiver or applications for awards upon request of the petitioner or applicant. A list of Board members appears in appendix H.

#### **Patent Waiver Petitions Granted or Denied**

During the period of this report, the Board reviewed six petitions for blanket waiver of title to patents of any invention made during the contract performance. It recommended that four be granted and two be denied. It also reviewed 31 petitions for waiver of title to individual inventions and recommended that 30 be granted and 1 denied. One public hearing was conducted at the request of the contractor.

In all cases, the instrument of waiver provides that the Government retain a royalty-free license to any patented invention. Waivers granted and denied by the Administrator during the period of this report are listed in appendix I.

#### **Contributions Awards**

During the reporting period the Board received 1,449 communications relating to scientific and technical contributions for consideration under section 306 of the Space Act. A total of 671 new contributions were evaluated. Two awards totaling \$3,500 were granted under the authority of section 306, one of these going to an employee of a NASA contractor. (App. J.)

#### **Inventions Awards**

By administrative regulation, the Board is authorized to make monetary awards upon its own cognizance in amounts not to exceed \$5,000 for certain inventions made by NASA employees which do not qualify for Space Act awards. Eighty-eight employee-inventors shared in

awards totaling \$27,100 made by the Board under this regulation for 61 inventions on which patent applications were filed by NASA. (App. K.)

### **Organizational and Managerial Improvements**

Several organizational elements of NASA were realigned during the last half of 1965, and a major managerial process to improve project planning was adopted.

#### **Realignment in the Office of the Administrator**

In conjunction with the appointment of NASA's former Associate Administrator to succeed the recently deceased Deputy Administrator, certain changes were made in the operating pattern for the Office of the Administrator. The essential aspects of these changes center on delegations of authority and responsibility to the Deputy Administrator, enabling him to serve on a day-to-day basis as general manager of the Agency and as Acting Administrator in the absence of the Administrator.

Other principal features of the realignment in the Office of the Administrator include the following:

An Associate Deputy Administrator who serves as the principal assistant to the Administrator and Deputy Administrator. He is responsible for policy planning and for general supervision of the administrative and other processes whereby the work of the Agency is accomplished, including a strengthened executive secretariat.

An executive secretariat responsible for channeling, expediting, and scheduling the flow of work in the Office of the Administrator; for ascertaining that matters coming to that office are properly prepared and reflect pertinent policy or substantive content needed for final action; for communicating decisions within the Office of the Administrator to appropriate NASA officials; and for related supporting functions. (See NASA organizational chart, fig. 10-1.)

Continued emphasis was placed on NASA-wide functional coordination and supervision of policy and administration. All functional staff offices report to the Deputy Administrator. Together, they constitute a single central functional staff, serving the Office of the Administrator and the Associate Administrators in charge of program offices to the fullest extent possible.

#### **Civilian-Military Liaison Committee Abolished**

The Civilian-Military Liaison Committee, established by section 204 of the National Aeronautics and Space Act of 1958, was abolished and its functions transferred to the President under terms of the President's Reorganization Plan No. 4 of 1965 as enacted into law.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

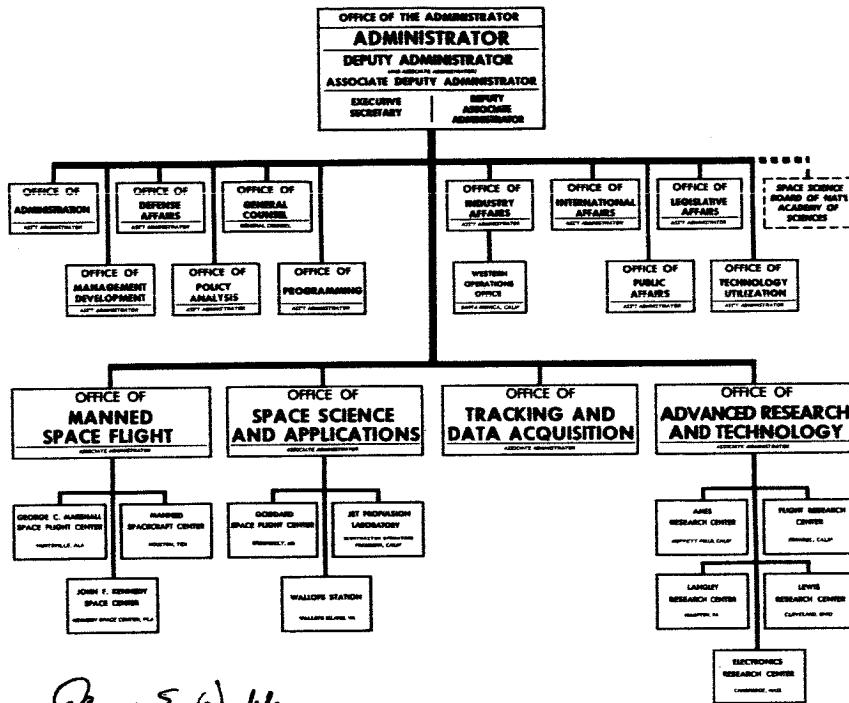


Figure 10-1. NASA organization chart.

### Facilities Management Office Established

A Facilities Management Office was established as a new organizational unit under the Office of Industry Affairs. The newly established unit will provide within NASA Headquarters a centralized office responsible for developing agency policies, criteria, and operational practices in managing NASA-controlled facilities and real property. The Office also reviews, evaluates, and reports on Agency facility management practices in such areas as design, acquisition, construction, repair, alteration, maintenance, operation, utilization and disposal. Facilities management functions previously assigned to various organizational elements of headquarters will be merged and placed

under the new Office. The former Director of Management Coordination, Office of Administration, was appointed as Director of the Facilities Management Office.

#### **Saturn/Apollo Applications Office Established**

A Saturn/Apollo Applications Office was established in the headquarters' Office of Manned Space Flight and was assigned the role of developing plans for future programs to achieve maximum use and exploitation of Saturn/Apollo capabilities.

#### **Tracking and Data Acquisition Organization Realined**

Several changes were made in the organization of the Office of Tracking and Data Acquisition (OTDA) to reflect the recently assigned responsibility for Agency-wide management of automatic data processing and to consolidate related functions in other areas. An ADP Management Branch was established within the Operations, Communications, and ADP Division to integrate the ADP management function into the Office of Tracking and Data Acquisition organization.

A Systems Planning and Development Division was established which absorbed the former Program Support and Advanced Systems Division under the same director. The realinement strengthens planning, development, and systems analysis capabilities by disassociating these functions from the immediate problems of support operations.

A Network Operations Implementation Division was established and network implementation functions, previously located in several divisions throughout OTDA, were consolidated and placed under the new division.

#### **Launch Operations Activities Consolidated**

Responsibility for NASA launch operations and facilities at Merritt Island and at the Eastern and Western Test Ranges was consolidated by transferring to the Director of the John F. Kennedy Space Center responsibility for the Goddard Space Flight Center division already located at the Kennedy Center, and for the Pacific Launch Operations Office located at Lompoc, Calif. The Wallops Station was not included in this consolidation.

#### **Phased Project Planning Established**

In October, NASA formally established as policy a system of sequential phases in the approval and execution of major research and development projects. Under this system, called phased project

planning, each phase (Advanced Studies, Project Definition, Design, and Development/Operations) involves a combination of competitive industrial participation and complementary Government inhouse effort. The system increases flexibility for management to react favorably to technological breakthroughs and significant changes in Agency or national policy and requirements.

Phased project planning is not an end in itself, but represents a major step in evolving a management pattern of maximum effectiveness. This policy is designed to help achieve better project definition (technical, schedule, management, and resources); to minimize undesirable technical, schedule, and cost changes; and to encourage use of fixed price or incentive cost-type contracts.

Each of the four phases is a specifically approved activity undertaken after review and analysis of preceding efforts. In addition, each is a coherent, focused effort with definable end objectives and represents a specific limited Agency commitment, both internally and externally.

### **Financial Management**

As a part of NASA's continuing effort to improve its financial management, the Agency's First Annual Financial Management Conference was held in September 1965. This conference gave the fiscal, financial management, and resources management officials of NASA's various installations an opportunity to become more familiar with each other's organizations and methods. The interchange of novel and different approaches to common problems should raise the general level of performance of the financial management function.

Another means of improving the consistency and effectiveness of the financial management function was provided by functional reviews at the field installations by headquarters staff officials. The first cycle of such reviews was completed during the reporting period. The reviews are conducted to (1) provide familiarity with local conditions as an aid to establishment of better agencywide policies, (2) identify areas of weakness, (3) assist in solving specific problems, and (4) foster the exchange of ideas for the improvement of performance.

Congressional approval was obtained for initially financing from one appropriation, work or activities for which adjustments shall subsequently be made to other benefiting appropriations. This authority will be particularly useful in connection with many types of contracts for common-use materials, supplies, and services applicable to a number of programs or projects where an accurate distribution of charges cannot be made at the time of obligation, or perhaps even at the time of payment. Another useful authorization granted at

NASA's request permits the letting of contracts under the 1-year administrative operations appropriation for maintenance and operation of facilities, and for other services, for periods extending into the following fiscal year. This should help to level out the peaks in administrative workloads.

An example of interagency cooperation for better management practices resulted from a study of NASA's foreign policies and procedures at the Manned Spacecraft Center in Houston, Tex. By special arrangements with the Department of State, a NASA employee was designated as a Passport Agent representing the Department of State at the Manned Spacecraft Center. Thus, the maintenance and re-validation of passports, necessary to the timely clearance and funding of authorized foreign travel, can be performed more directly and expeditiously.

#### Fiscal Year 1967 Program

Table 1 shows the planned level of effort in research, development, construction of facilities, and administrative operations for fiscal year 1967.

**Table 1.—NASA budget estimates, fiscal year 1967**

[In thousands]

Research and development:	
Gemini-----	\$40,600
Apollo-----	2,974,200
Advanced mission studies-----	8,000
Physics and astronomy-----	167,300
Lunar and planetary exploration-----	260,800
Bioscience-----	39,900
Launch vehicle development-----	61,700
Space applications-----	88,100
Space technology-----	247,900
Aircraft technology-----	33,000
Tracking and data acquisition-----	279,300
Sustaining university program-----	41,000
Technology utilization-----	4,800
Total, research and development-----	4,246,600
Construction of facilities-----	101,500
Administrative operations-----	663,900
Total-----	5,012,000

#### Financial Reports, December 31, 1965

Table 2 shows fund obligations, and accrued costs, and total disbursements of the first 6 months of fiscal year 1966. Appended is a summary by appropriation showing current availability, obligations against this availability, and unobligated balances as of December 31, 1965.

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**Table 2.—Status of appropriations as of December 31, 1965**

[In thousands]

<i>Appropriations</i>	<i>Obligations</i>	<i>Accrued costs</i>
<b>Research and development:</b>		
Gemini	\$119, 516	\$125, 347
Apollo	1, 746, 892	1, 575, 982
Advanced missions	7, 157	9, 743
Completed missions	175	207
Physics and astronomy	66, 954	58, 923
Lunar and planetary exploration	138, 275	89, 843
Sustaining university program	9, 047	11, 485
Launch vehicle development	24, 925	30, 461
Unmanned vehicle procurement	73, 951	83, 737
Bioscience	18, 624	15, 828
Meteorological satellites	19, 402	13, 590
Communications satellites	1, 017	1, 864
Applications technology satellites	21, 646	20, 454
Manned space sciences	9, 191	7, 229
Basic research program	8, 958	9, 401
Space vehicle systems	13, 125	13, 004
Electronics systems	11, 899	11, 968
Human factor systems	5, 507	5, 518
Nuclear-electric systems	9, 094	16, 686
Nuclear rockets	40, 971	30, 182
Chemical propulsion	15, 382	26, 590
Chemical and solar power	3, 888	6, 406
Aeronautics	12, 390	18, 080
Tracking and data acquisition	124, 277	95, 022
Technology utilization	1, 161	1, 901
Operations	(173)	(173)
Reimbursable	56, 162	36, 771
 Total, research and development	2, 559, 413	2, 316, 049
Construction of facilities	114, 590	293, 169
Administrative operations	307, 709	283, 303
 Total obligations	2, 981, 712	
 Total accrued costs		2, 892, 521
Less unpaid costs		(29, 957)
 Total gross disbursements		2, 862, 564
 <i>Appropriation summary</i>	<i>Current availability</i> <sup>1</sup>	<i>Total obligations</i>
Research and development	\$4, 830, 731	\$2, 559, 413
Construction of facilities	377, 977	114, 590
Administrative operations	595, 373	307, 709
		<i>Unobligated balance</i>
		\$2, 271, 318
		263, 387
		287, 664

<sup>1</sup> The availability listed includes anticipated reimbursable authority.

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Table 3 shows NASA's consolidated balance sheet as of December 31, 1965, as compared to that of June 30, 1965. Table 4 summarizes the sources and applications of NASA's resources during the 6 months ended December 31, 1965. Table 5 provides an analysis of the net change in working capital disclosed in table 4.

Table 3.—NASA comparative consolidated balance sheet, Dec. 31, 1965 and June 30, 1965

[In millions]

ASSETS	<i>Dec. 31, 1965</i>	<i>June 30, 1965</i>
Cash:		
Funds with U.S. Treasury-----	<u>\$5,691.6</u>	<u>\$3,354.6</u>
Accounts receivable:		
Federal agencies-----	26.9	13.3
Other-----	.8	.5
Total-----	<u>27.7</u>	<u>13.8</u>
Inventories-----	<u>90.8</u>	<u>78.4</u>
Advances and prepayments:		
Federal agencies-----	7.4	4.3
Other-----	32.9	15.7
Total-----	<u>40.3</u>	<u>20.0</u>
Fixed assets:		
NASA-held-----	1,693.9	1,481.3
Contractor-held-----	416.8	414.8
Construction work in progress-----	1,179.3	999.8
Total-----	<u>3,290.0</u>	<u>2,895.9</u>
Total assets-----	<u>9,140.4</u>	<u>6,362.7</u>
LIABILITIES AND NASA EQUITY		
Liabilities:		
Accounts payable:		
Federal agencies-----	248.8	196.6
Other-----	737.4	737.0
Total liabilities-----	<u>986.2</u>	<u>933.6</u>
NASA equity:		
Net investment of the United States-----	2,429.8	2,058.8
Undisbursed allotments-----	4,718.8	3,329.4
Unapportioned and unallotted appropriation-----	1,172.5	143.5
Reimbursable disbursing authority uncollected-----	(166.9)	(102.6)
Total NASA equity-----	<u>8,154.2</u>	<u>5,429.1</u>
Total liabilities and NASA equity-----	<u>9,140.4</u>	<u>6,362.7</u>

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Table 4.—Resources provided and applied for the 6 months ended Dec. 31, 1965

[In millions]

RESOURCES PROVIDED		Total current year costs	Less costs applied to assets	
Appropriations:				
Research and development	-----	-----	-----	\$4,499.5
Construction of facilities	-----	-----	-----	84.5
Administrative operations	-----	-----	-----	591.0
Total appropriations	-----	-----	-----	5,175.0
Revenues	-----	-----	-----	38.7
Total resources provided	-----	-----	-----	5,213.7
RESOURCES APPLIED				
Operating costs:				
Research and development	\$2,316.1	\$99.9	2,216.2	
Construction of facilities	293.2	293.2	0	
Administrative operations	283.3	19.5	263.8	
Total	2,892.6	412.6	-----	
Total operating costs	-----	-----	-----	2,480.0
Increase in fixed assets:				
NASA-held	-----	-----	212.6	
Contractor-held	-----	-----	2.0	
Construction in progress	-----	-----	179.5	
Total increase in fixed assets	-----	-----	394.1	
Property transfers and retirements—net	-----	-----	8.6	
Increase in working capital	-----	-----	-----	2,331.0
Total resources applied	-----	-----	-----	5,213.7

Table 5.—Net change in working capital for the 6 months ended Dec. 31, 1965

	[In millions]		
	Dec. 31, 1965	July 1, 1965	Increase or decrease
Current Assets:			
Funds with U.S. Treasury-----	5,691.6	3,354.6	2,337.0
Accounts receivable-----	27.7	13.8	13.9
Inventories-----	90.8	78.4	12.4
Advances and prepayments-----	40.3	20.0	20.3
Total current assets-----	5,850.4	3,466.8	2,383.6
Current Liabilities:			
Accounts payable-----	986.2	933.6	52.6
Total current liabilities-----	986.2	933.6	52.6
Working capital-----	4,864.2	2,533.2	
Increase in working capital-----			2,331.0

### Cost Reduction

Organization and general direction of the NASA cost reduction program remained stable during the period. Overall management is assigned to the NASA Cost Reduction Board chaired by the Deputy Associate Administrator and assisted by a permanent staff. Each headquarters program and staff office and each installation has designated a key management official to direct its program. Each has also designated cost reduction officers to assist in carrying it out.

Close and frequent contacts between headquarters and field activities contributed materially to strengthening local programs and assisting NASA activities in achieving their goals. A training seminar was conducted at MSC, Houston, in October 1965. Working seminars, such as this, have helped develop new ideas and techniques and have improved interagency communication in applying new policies and procedures.

NASA's overall cost reduction activities are composed of: (1) An internal program encompassing all of the Agency's field centers, headquarters, and other activities; and (2) a contractor cost reduction program based on the voluntary formal participation of 39 of NASA's major contractors.

With respect to the internal cost reduction program, NASA field installations and headquarters activities continued to submit proposed cost reduction goals on an annual basis. These proposed goals are independently reviewed, and a final allocation of goals is made by the NASA Cost Reduction Board. Progress against goals is monitored by the Cost Reduction Board on a quarterly basis. All

individual cost reduction actions which are credited to the goals of the respective NASA activities and to the overall Agency goal are reviewed by the Cost Reduction Board staff.

Since the inception of formal reporting, NASA has reported savings of \$343 million to the President resulting from its internal program. A goal of \$150 million was established for fiscal year 1966. The actions taken to meet this goal will be limited to those things which can be done without compromising NASA's mission responsibility.

Items reported as cost reductions in NASA's internal program which appear to have the potential for wider application are disseminated semiannually throughout NASA and to NASA contractors in a publication entitled *NASA BITS*.

NASA's contractor cost reduction program was initiated in December 1963. Thirty-nine major contractors participate in NASA's program and are assigned among the various NASA field installations for purposes of cost reduction. Their programs are formally evaluated and they submit semiannual reports to NASA on their cost reduction accomplishments. If a contractor's program does not meet NASA's standards it is not approved and the contractor is so advised. NASA representatives then work with the contractor to bring his program up to NASA standards. This has proved to be an effective technique.

NASA does not require that contractors reveal their goals to NASA but does require, among other things, that they have an effective system for establishing and monitoring goals. Only those savings which meet NASA's criteria are accepted and included in reports to the President. Since the inception of formal reporting, \$202 million in savings by NASA contractors have so been reported.

Those savings techniques reported by contractors which appear to have potential for wider application are disseminated in a NASA publication entitled *TRIM*.

NASA's procurement regulation provides for the mandatory inclusion in all proposed procurements in excess of \$1 million of a statement in the request of proposal which requires submission of information on the offeror's cost reduction program with his proposal. This information is evaluated by NASA and given consideration in source selection and in negotiation of fees or profits.

### **Procurement**

NASA's procurement activities during the period placed increased emphasis on improved contract administration. In addition, continued stress was given to incentive contracting and to subcontracting practices. Of a major importance was the legislation enabling the

Agency to obtain certain maintenance, facilities operation, and support services funded on a 12-month basis without regard to the end of the current fiscal year.

#### **NASA Policy on Contract Administration**

NASA issued a revised regulation, effective October 1, 1965, setting forth its policy with respect to the maximum use of the contract administration capabilities of the Department of Defense and other Government agencies. Such use is expected to result in more effective contract administration. Many contractors are doing business with both NASA and the Department of Defense, and NASA's use of the DOD contract management organization makes it unnecessary to establish duplicate capabilities within NASA.

Subsequently (December 17), the Agency issued instructions to all of its installations, implementing this policy. These instructions were in the form of a standard letter of delegation for contract administration functions for cost reimbursement contracts. Uniform implementation of the NASA policy will result from the use of standard letters of delegation.

During the period, NASA completed establishment of its own regional offices co-located with each of the 11 Defense Contract Administration Services Region (DCASR) offices. These field offices, reporting administratively to the NASA Office of Procurement, provide for the coordination of matters related to the administration of NASA contracts by the Defense Supply Agency. Each NASA/DCASR office is staffed by one or two NASA employees, with secretarial assistance and administrative support provided by the Defense Supply Agency. This plan has already proved effective in facilitating the transition of NASA contract administration from the military departments to the Defense Supply Agency, implementing the National Plan for the Consolidation of Contract Administration Services (Project 60).

#### **Use of the Defense Contract Audit Agency Capabilities**

Following the consolidation of the audit organizations of the Army, Navy, and Air Force into the Defense Contract Audit Agency (DCAA), on September 11, 1965, instructions were issued to all NASA installations setting forth the procedures to be used for requesting audit services. These instructions were in the form of a standard letter of delegation to be sent to the cognizant DCAA field audit office by NASA contracting officers. The use of standard letters of delegation will result in more efficient coordination between NASA and DCAA.

### **Contract Administration Personnel Training**

NASA developed a training course for personnel engaged in the administration of NASA contracts. The course is part of a program to improve and increase the effectiveness of contract administration.

### **Letter Contracts**

Necessary implementing procedures were developed for the NASA procurement regulations for guidance on the use of letter contracts. The regulation now clearly stipulates the Agency's policy not to use such contracts. Any request for a deviation from this policy requires the review and personal approval of the Deputy Administrator. As of December 31, 1965, there were no outstanding letter contracts.

This emphasis on curtailing the use of letter contracts is resulting in greater discipline for advanced planning of programs and providing for definitive contract terms and conditions with contractors at the outset.

### **Contracting for Services Across Fiscal Years**

The NASA Authorization Act, 1966 (Public Law 89-53, June 28, 1965) and the Independent Offices Appropriation Act, 1966 (Public Law 89-128), approved August 16, 1965, enable NASA to enter into contracts for the procurement of maintenance and operation of facilities and for support services funded with "1-year money" for 12-month periods without regard to the end of the current fiscal year.

Prior to the enactment of these two laws, "Administrative Operations" appropriations (1-year money) were not available for payments under severable contracts for such services rendered at any time after the end of the fiscal year for which the funds were appropriated. In order to obtain such services in the following fiscal year, either the entire procurement process had to be undertaken again, options had to be exercised, or some similar device used at fiscal year end, placing a further administrative burden on the Government. As a consequence, contractors' bids or proposals were not as low as otherwise possible, particularly where substantial "startup" costs were involved. Thus, the July-to-June procurement cycle resulted in excessive administrative costs, scheduling difficulties, and high bids and proposals.

Through the use of this new authority, it is expected that contract administration will be improved and the higher costs of contracting on a July-June cycle reduced.

### **Incentive Contracting**

NASA continued to emphasize the use of incentive arrangements in contracts whenever such use advances the procurement objectives of the

space program. During the period, NASA awarded 41 new incentive contracts having a target value of \$262 million and converted 2 cost-plus-fixed-fee contracts to incentive contracts having a target value of \$47 million. Changes, extensions, and additions to existing incentive contracts less the value of incentive contracts completed during the period amounted to \$40 million. Thus, as of December 31, 1965, NASA had under administration 159 incentive contracts with an aggregate target value of \$2,184 million. This was \$349 million more than the target value of active incentive contracts as of June 30, 1965.

Major new incentive contracts awarded during the period were (in millions of dollars) : NAS5-9146, Advanced Orbiting Solar Observatories with Republic Aviation Corp. (now a division of Fairchild Hiller), \$58.4; NAS9-4810, Gemini/Apollo Mission Trajectory and Apollo Spacecraft Systems Analysis with TRW Systems Group, TRW, Inc., \$51.8; NAS5-9870, Operation, Maintenance, Logistic and Engineering Services for the Manned Space Flight Network with Bendix Field Engineering Co., \$33.7; NAS8-15494, Research and Development Program for RL-10 Rocket Engine with Pratt and Whitney Division, United Aircraft Corp., \$19.4; NAS8-15486, C-1 Rocket Engine Development Program with Thiokol Chemical Corp., \$17.3; and NAS7-336, Delta Space Research Vehicles with Douglas Aircraft Co., Inc., \$16.2.

The major conversion completed in the period was (in millions of dollars) : NASw-16, Development of Saturn V, F-1 Engine with Rocketdyne Division, North American Aviation, Inc., \$41.8.

#### **Summary of Contract Awards**

NASA's procurement for the first 6 months of fiscal year 1966 totaled \$2,779 million. This is 5 percent less than was awarded during the corresponding period of fiscal year 1965.

Approximately 83 percent of the net dollar value was placed directly with business firms, 2 percent with educational and other nonprofit institutions, 5 percent with the California Institute of Technology for operation of the Jet Propulsion Laboratory, 9 percent with or through other Government agencies, and 1 percent outside the United States.

#### **Contracts Awarded to Private Industry**

Ninety percent of the dollar value of procurement requests placed by NASA with other Government agencies resulted in contracts with industry awarded by those agencies on behalf of NASA. In addition, about 77 percent of the funds placed by NASA under the Jet Propulsion Laboratory contract resulted in subcontracts or purchases with business firms. In short, about 95 percent of NASA's procurement dollars was contracted to private industry.

Sixty-five percent of the total direct awards to business represented competitive procurements, either through formal advertising or competitive negotiation. An additional 11 percent represented actions on follow-on contracts placed with companies that had previously been selected on a competitive basis to perform the research and development on the applicable project. In these instances, selection of another source would have resulted in additional cost to the Government by reason of duplicate preparation and investment. The remaining 24 percent included contracts for facilities required at contractor's plants for performance of their NASA research and development effort, contracts arising from unsolicited proposals offering new ideas and concepts, contracts employing unique capabilities, and procurements of sole-source items.

Small business firms received \$115 million, or 5 percent of NASA's direct awards to business. However, most of the awards to business were for large, continuing research and development contracts for major systems and major items of hardware. These are generally beyond the capability of small business firms on a prime contract basis. Of the \$258 million of new contracts of \$25,000 and over awarded to business during the 6 months, small business received \$50 million, or 19 percent.

In addition to the direct awards, small business received substantial subcontract awards from 60 of NASA's prime contractors participating in its small business subcontracting program. Total direct awards plus known subcontract awards aggregated \$335 million, or 15 percent of NASA's total awards to business during the first half of 1966.

#### **Geographical Distribution of Prime Contracts**

Within the United States, NASA's prime contract awards were distributed among 42 States and the District of Columbia. Business firms in 41 States and educational institutions and other nonprofit institutions in 38 States participated in the awards. Five percent of the awards went to labor surplus areas located in 15 States.

#### **Subcontracting**

Subcontracting effected a further distribution of the prime contract awards. NASA's major prime contractors located in 23 States and the District of Columbia reported that their larger subcontract awards on NASA effort had gone to 1,339 subcontractors in 44 States and the District of Columbia, and that 66 percent of these subcontract dollars had crossed State lines.

### Major Contract Awards

Among the major research and development aggregate contract awards by NASA during the first 6 months of fiscal year 1966 were the following:

- (1) North American Aviation, Inc., Downey, Calif., NAS9-150. Design, develop and test three-man earth to moon and return Apollo spacecraft. Awarded \$364 million; cumulative awards \$1,816 million.
- (2) Grumman Aircraft Engineering Corp., Bethpage, N.Y., NAS9-1100. Lunar excursion module development for the Apollo program. Awarded \$181 million; cumulative awards \$523 million.
- (3) North American Aviation, Inc., Downey, Calif., NAS7-200. Design, develop, fabricate, and test the S-II stage of the Saturn V vehicle. Awarded \$173 million; cumulative awards \$606 million.
- (4) The Boeing Co., New Orleans, La., NAS8-5608. Design, develop, and fabricate the S-IC stage of the Saturn V vehicle and construct facilities in support of the S-IC stage. Awarded \$172 million; cumulative awards \$655 million.
- (5) Douglas Aircraft Co., Inc., Santa Monica, Calif., NAS7-101. Design, develop, and fabricate the S-IVB stage of the Saturn V vehicle and associated ground support equipment. Awarded \$124 million; cumulative awards \$501 million.
- (6) General Electric Co., Daytona Beach, Fla., NASw-410. Overall integration, checkout, and reliability of Apollo space vehicle system. Awarded \$107 million; cumulative awards \$350 million.
- (7) General Motors Corp., Milwaukee, Wis., NAS9-497. Guidance computer subsystem for Apollo command service module. Awarded \$71 million; cumulative awards \$183 million.
- (8) North American Aviation, Inc., Canoga Park, Calif., NAS8-5603. Procure 200,000-pound thrust J-2 rocket engines with supporting services and hardware. Awarded \$65 million; cumulative awards \$182 million.
- (9) Aerojet General Corp., Azusa, Calif., SNP-1. Design, develop and produce a nuclear-powered rocket engine (NERVA). Awarded \$62 million; cumulative awards \$325 million.
- (10) Chrysler Corporation, New Orleans, La., NAS8-4016. Fabricate, assemble, checkout and static test Saturn S-1 stage. Provide product improvement program and spare parts support. Modify areas of Michoud plant assigned to contractor. Awarded \$45 million; cumulative awards \$282 million.
- (11) North American Aviation, Inc., Canoga Park, Calif., NAS8-5604. Procure 1,500,000-pound thrust F-1 rocket engines with

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supporting services and hardware. Awarded \$45 million; cumulative awards \$167 million.

(12) McDonnell Aircraft Corp., St. Louis, Mo., NAS9-170. Design and develop two-man Gemini spacecraft. Awarded \$41 million; cumulative awards \$699 million.

(13) North American Aviation, Inc., Canoga Park, Calif., NAS8-19. Develop 200,000-pound thrust J-2 rocket engine. Awarded \$37 million; cumulative awards \$233 million.

(14) The Boeing Co., Seattle, Wash., NAS1-3800. Develop and fabricate lunar orbiter spacecraft systems. Awarded \$34 million; cumulative awards \$103 million.

(15) General Dynamics Corp., San Diego, Calif., NAS3-3232. Develop, fabricate, and deliver Centaur vehicles and support equipment. Awarded \$29 million; cumulative awards \$285 million.

(16) North American Aviation, Inc., Canoga Park, Calif., NASw-16. Develop and fabricate 1,500,000-pound thrust F-1 rocket engine. Awarded \$29 million; cumulative awards \$320 million.

(17) International Business Machines Corp., Rockville, Md., NAS8-14000. Fabrication, assembly, and checkout of instrument units for Satlurns IB and V vehicles. Awarded \$28 million; cumulative awards \$64 million.

(18) Fairchild Hiller, Farmingdale, N.Y., NAS5-9146. Design, develop, fabricate, and test phase II advanced Orbiting Solar Observatory. Awarded \$14 million (new contract).

(19) Hughes Aircraft Co., Culver City, Calif., NAS5-3823. Develop and test advanced technological spacecraft. Awarded \$14 million; cumulative awards \$34 million.

(20) Bendix Corp., Teterboro, N.J., NAS8-13005. Stablized platform systems and associated hardware for Saturn IB and Saturn V vehicles. Awarded \$12 million; cumulative awards \$22 million.

**Major Contracts**

The 25 contractors receiving the largest direct awards (net value) during the first 6 months of fiscal year 1966 were as follows:

<i>Contractor and place of contract performance</i>	<i>Net value of awards** (thousands)</i>
North American Aviation, Inc., Downey, Calif.*-----	731, 220
Boeing Co., New Orleans, La.*-----	208, 512
Grumman Aircraft Engineering Corp., Bethpage, N.Y-----	187, 698
Douglas Aircraft Co., Inc., Santa Monica, Calif.*-----	142, 337
General Electric Co., Huntsville, Ala.*-----	141, 268
Aerojet-General Corp., Sacramento, Calif.*-----	83, 223
General Motors Corp., Milwaukee, Wis.*-----	74, 652
International Business Machines Corp., Huntsville, Ala.*-----	57, 348
Chrysler Corp., New Orleans, La.*-----	46, 282
McDonnell Aircraft Corp., St. Louis, Mo-----	44, 682
General Dynamics Corp., San Diego, Calif.*-----	37, 053
Bendix Corp., Teterboro, N.J.*-----	32, 477
TRW Inc., Redondo Beach, Calif.*-----	24, 683
Radio Corp. of America, Van Nuys, Calif.*-----	20, 269
Lockheed Aircraft Corp., Sunnyvale, Calif.*-----	20, 029
United Aircraft Corp., West Palm Beach, Fla.*-----	17, 038
Fairchild Hiller Corp., Farmingdale, N.Y.*-----	16, 431
Hughes Aircraft Co., Culver City, Calif.*-----	16, 216
LTV Aerospace Corp., Dallas, Tex.*-----	16, 193
Brown Engineering Co., Huntsville, Ala.*-----	13, 902
Sperry Rand Corp., Huntsville, Ala.*-----	11, 790
Union Carbide Corp., Sacramento, Calif.*-----	11, 773
Philco Corp., Houston, Tex.*-----	11, 332
Hayes International Corp., Birmingham, Ala.*-----	10, 560
Bellcomm, Inc., Washington, D.C.-----	10, 087

\*Awards during period represent awards on several contracts which have different principal places of performance. The place shown is that which has the largest amount of the awards.

\*\*Data for individual companies include awards on R. & D. contracts of \$10,000 and over and on all other contracts of \$25,000 and over.

## Labor Relations

During the last half of 1965 losses of man-days due to labor disputes fell significantly at all NASA centers, particularly at the John F. Kennedy Space Center. Moreover, most of the man-days lost in this period at Kennedy Space Center were attributable to work stoppages at industrial plants of two aerospace contractors, the Boeing Co. and McDonnell Aircraft Corp.

From September 16 through October 5, 1965, a labor dispute between the International Association of Machinists and the Boeing Co. over terms for renewal of their national contract caused work stoppages at Kennedy Space Center, Michoud Operations, and Marshall Space Flight Center. About 29,000 man-days were lost at these centers on account of this strike. From November 19 through November 23, 1965, a work stoppage by the machinists at the McDonnell Aircraft Corp.'s St. Louis plant caused their Gemini service crew to stop work at Kennedy Space Center for 3 days. Upon interven-

tion by the Secretary of Labor and the Federal Mediation and Conciliation Service, this crew was persuaded to resume work on the launches of Geminis VII and VI-A.

The end of calendar year 1965 saw the successful completion of national labor negotiations in the aerospace industry, except for one agreement, at General Dynamics/Fort Worth. (Bargaining sessions at Fort Worth were still in progress at year's end.) Virtually all the new contracts in aerospace were negotiated with the assistance of the Federal Mediation and Conciliation Service. NASA continued to coordinate its labor relations activity with that Service as well as with the Department of Labor, the Department of Defense, and the President's Missile Sites Labor Commission.

On October 22, 1965, the Service Contract Act of 1965 was enacted. The effective date of this new legislation was January 20, 1966. The act provides new requirements for minimum wages to cover various classes of service employees, including guards, janitors, and food service workers. This new law should provide some additional stability in labor relations between service contractors and unions representing their employees.

### **Technology Utilization**

During this period a careful review was made of the organization and management of the Office of Technology Utilization. As a result of this review, one of the five branches of the Technology Utilization Division was abolished and its functions transferred to each of the four remaining branches.

Another development during this period was the initiation of joint technology utilization programs between NASA and other Federal agencies. An interagency agreement was completed with the Small Business Administration to develop techniques and methods by which small business can obtain maximum benefit from NASA Regional Dissemination Center services. NASA anticipates that similar programs will soon be developed with other Federal agencies.

### **Interagency Activities and Agreements**

NASA continued to maintain close coordination with other governmental agencies having an interest in aeronautics and space, and with both industry and the scientific community. This coordination is accomplished by direct and frequent contacts of personnel at all levels, through formal organizations such as the NASA-DOD Aeronautics and Astronautics Coordinating Board (AACB), through ad hoc groups and advisory boards, and through various agreements. The period covered by this report was an active one in this regard.

An ad hoc subpanel was established, under the AACB, to examine the areas of reusable launch vehicles and hypersonic propulsion. This subpanel is expected to review studies which were completed or were in progress under the sponsorship of both agencies, consider the potential future needs in these areas, identify the technological advances which would need to be made before developmental prototype systems could be considered, and arrive at recommendations for future coordinated actions.

The AACB Supporting Space Research and Technology Panel and the Launch Vehicle Panel were jointly reviewing selected technology programs. Included in the revision were large liquid fuel engines, large solid fuel engines, and the SNAP-8 nuclear power supply.

NASA and the DOD established guidelines for the use and operation of the Churchill Research Range in Canada. The U.S. operating costs of the range will be shared by both agencies. The National Research Council of Canada will manage the range.

NASA and the Department of the Air Force arrived at and signed an agreement whereby NASA will furnish liquid hydrogen to the Air Force on a reimbursable basis to meet Air Force programs as required.

The coordination between NASA and DOD on planned construction of new facilities or expansion of existing facilities coming under fiscal year 1967 funding was expected to be completed by January 15, 1966. The purpose of this annual coordination is to make sure that no unnecessary duplication exists in NASA and DOD planning in this area.

The Unmanned Spacecraft Panel of the AACB developed procedures to make certain that both agencies make the fullest use of available space for carrying secondary payloads on DOD and NASA satellites.

NASA acquired additional aircraft on loan from the DOD for use in support of space and aeronautics research, development, and testing programs. Included among the principal aircraft loaned by the DOD to NASA were one Army helicopter and four Navy aircraft.

The assignment of selected military personnel to tours of duty with NASA was continuing. As of December 31, 1965, 78 Army, 25 Navy, 184 Air Force, and 6 Marine Corps officers were on duty with NASA. Of particular interest was the assignment during the year of 92 Air Force officers with backgrounds in planning and conducting missile operations to the NASA Mission Control Center at Houston, Tex., in an on-the-job training program.

## **DR. HUGH LATIMER DRYDEN**

### **1898-1965**

Hugh Latimer Dryden was born in Pocomoke City, Md., on July 2, 1898. The family moved to Baltimore in 1907, and Dryden, a gifted and precocious student, graduated in 1913 from the high school known as Baltimore City College, first in a class of 172, shortly before his 15th birthday.

Entering Johns Hopkins University with advanced standing, he completed a regular B.A. curriculum in 3 years, receiving his degree (with honors) in 1916, and his A.M. in 1918.

In June of 1918 he joined the staff of the National Bureau of Standards in Washington, D.C., as an inspector of munitions gages, intending to return to graduate school on a fellowship in the fall. However, with the encouragement of Dr. Joseph S. Ames, head of the Johns Hopkins Physics Department, his plans were changed. He soon obtained a transfer into the newly formed wind tunnel section, and after Dr. Ames arranged to give courses to a number of Hopkins graduate students at the Bureau, Dryden was able to complete his thesis work on experiments carried out after hours in the NBS wind tunnel. He was granted the Ph. D. in physics in 1919, while employed at the Bureau of Standards, when he was just under 21—youngest student ever to obtain a Ph. D. at Johns Hopkins.

Thus began a long and distinguished professional career, devoted in its entirety to public service. He remained in the Government civil service in spite of the fact that over the years there were many offers of highly paid positions in private industry, as his knowledge, talent, and administrative skill became increasingly well known in the world scientific community.

"The airplane and I grew up together," he once said. "I saw my first airplane, the Antoinette airplane, flown by Hubert Latham in Baltimore on November 7, 1910 . . . I have had the good fortune to be associated with the great growth in aviation from that primitive vehicle to the jetliners of today and our beginning manned space flights in Mercury and Gemini. My education has been a continuing process ever since graduation and I hope that I may have the good fortune to witness the first landing of men on the moon within a very few years."

He married Mary Libbie Travers on January 29, 1920. Three children were born to the couple, a son and two daughters. Their son, Dr. Hugh L. Dryden, Jr., is an organic chemist, graduate of Johns Hopkins and the Massachusetts Institute of Technology, now with G. D. Searle Co., Skokie, Ill. Their older daughter, Mary Ruth, graduated from Goucher College and married Dr. Andrew H. Van Tuyl, mathematician at the Naval Ordnance Laboratory, Washington, D.C. Their younger daughter, Nancy Travers, a graduate of American University, teaches school in Montgomery County, Md.

Not long after his marriage, Dr. Dryden was named chief of the NBS aerodynamic physics section, in charge of wind tunnel research. Here he began the work on the problems of wind turbulence and boundary layer flow which later was to bring him international recognition. Many times during his career he was invited to attend international scientific meetings and to exchange his professional views with fellow experts from all over the world.

Some of his early basic research, which led to increased knowledge of aeronautical engineering and the design of improved airplanes, included development of the compensated hot-wire anemometer and associated equipment for quantitative measurement of the intensity and linear scale of wind tunnel turbulence, studies of the use of wire screens for increasing and decreasing the intensity of turbulence, the design and building of wind tunnels of very low turbulence, and measurements of the effects of turbulence on aerodynamic forces on models in wind tunnels. From this work Dr. Dryden and his collaborators were able to verify the correctness of a theory developed by Prandtl, Tollmien, and Schlichting many years earlier, but for which there had been no experimental evidence. This traced the onset of turbulence to the prior development of instability in the laminar flow.

The work of Dr. Dryden and his team on wind tunnel turbulence and boundary layer transition has been of great importance in all aeronautical developments. Predictions of the flight performance of our large military and transport aircraft are based on extrapolation of data obtained in wind tunnel tests of relatively small models. Dr. Dryden's work provided a basis for making this extrapolation intelligently and with good accuracy.

In collaboration with Dr. Lyman J. Briggs, Dr. Dryden made some of the earliest measurements of aerodynamic characteristics at high speeds. The first move in this area was dictated by an interest in the effects of the higher propeller rotational speeds and propeller diameters and consequently high tip velocities, which were required to absorb the increasing engine powers in the early 1920's.

These early measurements led to a later understanding of the limita-

tion of the propeller as a means for driving airplanes. Propeller tip speeds greater than the speed of sound produced prohibitively large losses in efficiency and consequently all late propeller development has been confined towards the absorption of power by wide blades and a greater number of blades.

This work on propellers was extended to supersonic speeds as a natural evolution of interest. This early work was supported by the National Advisory Committee for Aeronautics and published by it. The interest generated in the Langley staff led to the construction of a high-speed jet there and subsequently to the numerous high-speed wind tunnel facilities of today.

In the earliest tests, Dr. Briggs and Dr. Dryden measured the sharp increase in drag and decrease in lift that occurs as the speed of sound is approached in flight, and thus were among the first to discover the so-called transonic drag rise.

Dr. Dryden was also responsible for extensive investigations of the aerodynamics of aircraft bombs, and for the development of a practical method of designing the tail fins to insure stability. With E. J. Lorin, he standardized the design of a form of bomb which remained in use for many years, until airplanes eventually were able to approach the speed of sound.

His work in wind tunnel research and studies of aerodynamics, however, soon began to take in far more territory than the aircraft field alone. At the Chicago "Century of Progress" in 1933, he and his colleagues had an exhibit which demonstrated the effect of streamlining on automobiles—work which long preceded changes in design now thoroughly accepted in the automotive industry. Studies of the effects of hurricanes and high winds upon various types of building structures gradually led to more rational engineering design and improved building codes for materials and structures. His laboratory even helped resolve an argument between the National and American Leagues in 1938 over the standards for the "liveliness" of baseballs.

During World War II, Dr. Dryden became involved in the work of the National Defense Research Committee and its successor, the Office of Scientific Research and Development, under the leadership of Dr. Vannevar Bush. In Dryden's own words, "I headed an unusual group at the Bureau of Ordnance Experimental Unit, which developed the radar homing missile, Bat, which saw service during the Second World War. I also served as Deputy Scientific Director of the Army Air Force's Scientific Advisory Group headed by Theodore von Karman. The group was appointed by Gen. H. H. Arnold and many of us were in Europe on V-E Day in uniform with simulated rank to study the use of science by the various European countries."

After his wartime work was completed, Dr. Dryden became Assistant Director of the National Bureau of Standards in 1946, and 6 months later, Associate Director. In September of the following year he transferred from NBS to become Director of Research of the National Advisory Committee for Aeronautics (NACA), and, in 1949, Director of NACA, its highest full-time official.

Under his leadership, the activities of NACA's three large research laboratories and two research stations were expanded, reaching some 8,000 employees and an annual budget of about \$100 million. In 1947, NACA provided the technical foundation for the first manned supersonic flight in the history of aviation, an event which was the forerunner of present military airplanes which operate routinely at more than twice the speed of sound.

The first round of research planes was intended for studies of the problems of flying an airplane through the speed of sound. Under Dryden's leadership, more attention was turned to the problems of flight at very high speeds and very high altitudes and to the problems of space flight.

In 1954 Dr. Dryden became Chairman of the Air Force-Navy-NACA Research Airplane Committee formed to supervise the development of an airplane to explore some of the problems of space at the highest speeds and altitudes then feasible. The X-15 airplane developed for the task proved to be, and has continued to be, an extremely useful research tool for providing data for future space vehicles.

In October 1957, after the Soviet Union launched Sputnik I, Dr. Dryden took part in the activities of the executive branch and of the Congress which led to the formulation of the National Aeronautics and Space Act of 1958. As preparations were made for establishing a civilian agency to conduct the exploration of space for peaceful purposes, the NACA was selected as the largest building block of the new agency. Dr. Dryden helped to guide the program plans and the budgetary submission of the agency before its formal establishment. On August 8, 1958, President Eisenhower appointed him as Deputy Administrator of the agency. He was confirmed by the Senate on August 13, and served during the remainder of the Eisenhower administration under Dr. T. Keith Glennan, Administrator. His appointment was continued under the Kennedy and Johnson administrations with Mr. James E. Webb, as Administrator.

Project Mercury was developed and then organized with Dr. Dryden playing a major role. He shared with NASA Administrator James E. Webb the top responsibility for management of a \$5-billion-a-year program to explore space, to develop practical applications of space vehicles, to advance space science and technology, and to develop

boosters, spacecraft, and associated materials, equipment, and techniques to enable American explorers to journey to the moon, perform scientific experiments there, and return safely to earth before the end of the present decade.

The importance of the lunar exploration mission, Project Apollo, and its underlying philosophy, was clearly stated by Dr. Dryden soon after President Kennedy announced his key decision in 1961. Dr. Dryden's work was prominent in the studies that led to that decision.

During recent years, international cooperation was one of the most important aspects of Dr. Dryden's work with the space program. In 1959 he was appointed as one of two men to assist Ambassador Henry Cabot Lodge at the first meeting of the United Nations Committee on the Peaceful Uses of Outer Space. It has been generally agreed that his efforts were largely responsible for a proposal by NASA, in December of that year, for joint research with other nations to promote international space cooperation.

In the years that followed, after an exchange of correspondence between Premier Nikita S. Khrushchev and President Kennedy, Dr. Dryden was appointed by the President as the Nation's chief negotiator for peaceful space cooperation with the Soviet Union. Dryden engaged in a continuing series of talks with Academician Anatoli Blagonravov on the possibility of such cooperation; from these talks came agreements for limited, but nonetheless real, cooperation between the two countries, particularly in the fields of meteorology and communications.

Working toward international cooperation and world peace fitted in well with Dr. Dryden's philosophy. A man of deep and sincere religious faith, he was an ordained minister and a Bible teacher at the Calvary Methodist Church in Washington during most of his adult life. He found no conflict between science and religion.

Many honors and offices came to Dr. Dryden, including the following:

Home Secretary of the National Academy of Sciences since 1955; Charter Member, Honorary Fellow, and former President of the Institute of Aerospace Sciences; Honorary Fellow of the Royal Aeronautical Society, the British Interplanetary Society, and the Canadian Aeronautics and Space Institute; Fellow of the American Academy of Arts and Sciences; Foreign Associate Member of l'Academie des Sciences de l'Institut de France; Honorary Member, Hermann Oberth-Gesellschaft; Founding Member, National Academy of Engineering; Honorary Member, the American Society of Mechanical Engineers; and a member of numerous other professional societies and organizations.

He was a Trustee of the National Geographic Society.

He was the first American to deliver the Wright Brothers Annual Lecture before the Institute of the Aeronautical Sciences (1938). He was also the recipient of many awards for his services and contributions. These included the following:

Sylvanus Albert Reed Award (1920)

U.S. Army Air Forces' Medal of Freedom (1926), the second highest U.S. award

Presidential Certificate of Merit (1948)

Order of the British Empire (civilian division) (1948)

37th Wilbur Wright Memorial Lecture before the Royal Aeronautical Society (1949)

Daniel Guggenheim Medal (1950)

Wright Brothers Memorial Trophy (1955)

Ludwig Prandtl Memorial Lecture of the Wissenschaftliche Gesellschaft fur Luftfahrt (1958)

Career Service Award of the National Civil Service League (1958)

Baltimore City College Hall of Fame (1958)

President's Award for Distinguished Federal Civilian Service (1960)

Elliott Cresson Medal of the Franklin Institute (1961)

Langley Gold Medal of the Smithsonian Institution (1962)

First Theodore von Karman Lecture before the American Rocket Society (1962)

Rockefeller Public Service Award (1962)

John Fritz Medal (1963)

Gold Medal of the International Benjamin Franklin Society (1963)

First Annual Award Dr. Theodore von Karman Memorial Citation (1963)

Dr. Robert A. Goddard Memorial Trophy (1964)

Hill Space Transportation Award (1964)

His honorary degrees included these:

Polytechnic Institute of Brooklyn (Sc. D., 1949)

New York University (D. Eng., 1950)

Rensselaer Polytechnic Institute (D. Eng., 1951)

University of Pennsylvania (Sc. D., 1951)

Western Maryland College (Sc. D., 1951)

Johns Hopkins University (LL.D., 1953)

University of Maryland (D. Eng., 1955)

Adelphi College (LL.D., 1959)

South Dakota School of Mines and Technology (D. Eng., 1961)

Case Institute of Technology (Sc. D., 1961)  
American University (L.H.D., 1962)  
Northwestern University (Sc. D., 1963)  
Worcester Polytechnic Institute (Sc. D., 1964)  
Politecnico de Milan (M.E., 1964)  
Swiss Federal Institute of Technology (Sc. D., 1965)  
Princeton University (Sc. D., 1965)

## **Appendix A**

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### **Congressional Committees on Aeronautics and Space**

**(July 1-December 31, 1985)**

#### **Senate Committee on Aeronautical and Space Sciences**

**CLINTON P. ANDERSON**, New Mexico,  
*Chairman*  
**RICHARD B. RUSSELL**, Georgia  
**WARREN G. MAGNUSEN**, Washington  
**STUART SYMINGTON**, Missouri  
**JOHN STENNIS**, Mississippi  
**STEPHEN M. YOUNG**, Ohio  
**THOMAS J. DODD**, Connecticut  
**HOWARD W. CANNON**, Nevada

**SPESSARD L. HOLLAND**, Florida  
**WALTER F. MONDALE**, Minnesota  
**JOSEPH D. TYDINGS**, Maryland  
**MARGARET CHASE SMITH**, Maine  
**BOURKE B. HICKENLOOPER**, Iowa  
**CARL T. CURTIS**, Nebraska  
**LEN B. JORDAN**, Idaho  
**GEORGE D. AIKEN**, Vermont

#### **House Committee on Science and Astronautics**

**GEORGE P. MILLER**, California, *Chair-*  
*man*  
**OLIN E. TEAGUE**, Texas  
**JOSEPH E. KAETH**, Minnesota  
**KEN HECHLER**, West Virginia  
**EMILIO Q. DADDARIO**, Connecticut  
**J. EDWAED ROUSH**, Indiana  
**BOB CASEY**, Texas  
**JOHN W. DAVIS**, Georgia  
**WILLIAM F. RYAN**, New York  
**THOMAS N. DOWNING**, Virginia  
**JOE D. WAGGONNER, JR.**, Louisiana  
**DON FUQUA**, Florida  
**CARL ALBERT**, Oklahoma  
**ROY A. TAYLOR**, North Carolina  
**GEORGE E. BROWN, JR.**, California

**WALTER H. MOELLER**, Ohio  
**WILLIAM R. ANDERSON**, Tennessee  
**BROCK ADAMS**, Washington  
**LESTER L. WOLFF**, New York  
**WESTON E. VIVIAN**, Michigan  
**GALE SCHISLER**, Illinois  
**JOSEPH W. MARTIN, JR.**, Massachusetts  
**JAMES G. FULTON**, Pennsylvania  
**CHARLES A. MOSHER**, Ohio  
**RICHARD L. ROUDEBUSH**, Indiana  
**ALPHONZO BELL**, California  
**THOMAS M. PELLY**, Washington  
**DONALD RUMSFELD**, Illinois  
**EDWAED J. GURNEY**, Florida  
**JOHN W. WYDLER**, New York  
**BARBER B. CONABLE, JR.**, New York

## **Appendix B**

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### **NATIONAL AERONAUTICS AND SPACE COUNCIL**

(July 1-December 31, 1965)

**HUBERT H. HUMPHREY**, *Chairman*  
*Vice President of the United States*

**DEAN RUSK**  
*Secretary of State*

**ROBERT S. McNAMARA**  
*Secretary of Defense*

**JAMES E. WEBB**, *Administrator*  
*National Aeronautics and Space Administration*

**GLENN T. SEABORG**, *Chairman*  
*Atomic Energy Commission*

*Executive Secretary*  
**EDWARD C. WELSH**

## Appendix C

### NASA-DOD Aeronautics and Astronautics Coordinating Board and Panels

(December 31, 1965)

#### COCHAIRMEN

**Dr. ROBERT C. SEAMANS, Jr.**, Deputy Administrator, NASA

**Dr. JOHN S. FOSTER, Jr.**, Director of Defense Research and Engineering, DOD  
*Secretaries:* Mr. RICHARD J. GREEN, NASA; Mr. ALBERT WEINSTEIN, DDR&E,  
DOD

#### MEMBERS AT LARGE

**Adm. W. F. BOONE**, USN (Ret.), Assistant Administrator for Defense Affairs,  
NASA

**Mr. DEMARQUIS D. WYATT**, Assistant Administrator for Programming, NASA

**Dr. HOMER E. NEWELL**, Associate Administrator for Space Science and Applications, NASA

**Dr. ALEXANDER H. FLAX**, Assistant Secretary of the Air Force (R&D), DOD

**Mr. THOMAS F. ROGERS**, Deputy Director (Electronics and Information Systems),  
ODDR&E, DOD

**Mr. DANIEL J. FINK**, Deputy Director (Strategic and Space Systems), ODDR&E,  
DOD

#### AERONAUTICS PANEL

*Chairman:* **Rear Adm. NOEL A. M. GAYLER**, USN, Assistant Chief of Naval Operations, (Dev.), OP 07-B, Office of Chief of Naval Operations, DOD

*Vice Chairman:* **Mr. CHARLES W. HARPER**, Office of Associate Administrator for Advanced Research and Technology, NASA

#### MEMBERS

**Dr. FLOYD THOMPSON**, Langley Research Center, NASA

**Mr. MARK R. NICHOLS**, Langley Research Center, NASA

**Mr. WOODROW L. COOK**, Ames Research Center, NASA

**Lt. Col. FRANK E. COLE**, USAF, Staff Development Engineer, Flight Dynamics,  
DCS/R&D Directorate of Science and Technology

**Mr. T. C. MUSE**, Office of Director of Defense Research and Engineering, DOD

**Col. A. J. RANKIN**, USA, Office Chief of Research and Development, DOD

*Secretaries:* **Mr. JACK D. BREWER**, Office of Associate Administrator for Advanced Research and Technology, NASA; **Mr. CLEM WEISSMAN**, Assistant for Aircraft Systems, OPNAV, DOD

*Alternate:* **Maj. PHILIP J. CONLEY**, Jr., USAF, Missile and Aerodynamics,  
AFRDQPM

#### LAUNCH VEHICLE PANEL

*Chairman:* **Dr. ALEXANDER H. FLAX**, Assistant Secretary of the Air Force (R&D), DOD

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*Vice Chairman:* Mr. MILTON W. ROSEN, Office of Assistant Administrator for Defense Affairs, NASA

### **MEMBERS**

Mr. EDWARD Z. GRAY, Office of the Associate Administrator for Manned Space Flight, NASA

Mr. VINCENT L. JOHNSON, Office of Associate Administrator for Space Sciences and Applications, NASA

Mr. JOHN L. SLOOR, Office of Associate Administrator for Advanced Research and Technology, NASA

Capt. C. C. ANDREWS, USN, Bureau of Naval Weapons, DOD

Lt. Col. JAMES C. FITZPATRICK, Jr., Directorate of Development DCS/R&D, Headquarters USAF

Mr. HEINRICH J. WEIGAND, Directorate of Development DCS/R&D, Headquarters, USAF

*Secretaries:* Maj. ROMAIN C. FRUGE, USAF, DOD ; Mr. ALFRED M. NELSON, Office of Assistant Administrator for Programing, NASA

*Alternates:* Mr. A. O. TISCHLER, Office of Associate Administrator for Advanced Research and Technology, NASA ; Mr. JOE JONES, Office of the Assistant Secretary of the Air Force (R&D), DOD

### **MANNED SPACE FLIGHT PANEL**

*Chairman:* Dr. GEORGE E. MUELLER, Associate Administrator for Manned Space Flight, NASA

*Vice Chairman:* Dr. ALEXANDER H. FLAX, Assistant Secretary of the Air Force (R&D), DOD

### **MEMBERS**

Col. JACK BOLLERUD, USAF, Deputy Director, Space Medicine, Office of Manned Space Flight, NASA

Maj. Gen. DAVID M. JONES, USAF, Office of Associate Administrator for Manned Space Flight, NASA

Mr. EDWARD Z. GRAY, Office of Associate Administrator for Manned Space Flight, NASA

Brig. Gen. GLENN A. KENT, USAF, Deputy Director for Development Plans, DCS/R&D

*Alternate:* Col. CHESTER J. BUTCHER, USAF, Chief Space Plans Division, Directorate of Operational Requirements and Development Plans; Capt. H. L. ANDERTON, USN, Assistant Director Development Facilities, Astronautics and Ranges Division, OpNav, DOD

*Secretaries:* Lt. Col. RICHARD DENNEN, Space Division Directorate of Operational Requirements and Development Plans, Headquarters, USAF; Mr. JAY HOLMES, Office of Associate Administrator for Manned Space Flight, NASA

*Alternates:* Mr. JOHN H. DISHER, Office of Associate Administrator for Manned Space Flight, NASA ; Mr. FRANKLIN J. ROSS, Office of Assistant Secretary of the Air Force (R&D), DOD

### **SPACE FLIGHT GROUND ENVIRONMENT PANEL**

*Chairman:* Brig. Gen. CLIFFORD J. KRONAUER, USAF, Assistant Director (Ranges and Space Ground Support), ODDR & E, DOD.

*Vice Chairman:* Mr. EDMOND C. BUCKLEY, Associate Administrator for Tracking and Data Acquisition, NASA

**MEMBERS**

**Mr. GERALD M. TRUSZYNSKI**, Office of Associate Administrator for Tracking and Data Acquisition, NASA

**Mr. JOHN T. MENGEI**, Goddard Space Flight Center, NASA

**Capt. JOHN HOLCOME, USN (Ret.)**, Office of Associate Administrator for Manned Space Flight, NASA

**Capt. E. N. HITCHCOCK, Jr., USN**, Head, Range Support Branch, Office of Chief of Naval Operations (Dev.), DOD

**Col. GEORGE SAMMET, Jr., USA**, Assistant Director of Missiles and Space, Office of the Chief of Research and Development (OCRD), DOD

**Col. JAMES B. TAPP, USAF**, Chief of Ranges and Facilities Division, AFRDDC

**Secretaries:** Lt. Col. V. W. HAMMOND, USAF, ODDR&E, DOD; Mr. FREDERICK BYRANT, Office of Associate Administrator for Tracking and Data Acquisition, NASA

**Alternates:** Mr. H. R. BROCKETT, Office of Associate Administrator for Tracking and Data Acquisition, NASA; Col. JAMES W. HEYROTH, USAF, Deputy Chief of Ranges and Facilities Division, AFRDDC

**SUPPORTING SPACE RESEARCH AND TECHNOLOGY PANEL**

**Chairman:** Dr. MAC C. ADAMS, Associate Administrator for Advanced Research and Technology, NASA

**Vice Chairman:** Dr. CHALMERS W. SHERWIN, Deputy Director (Research and Technology), ODDR&E, DOD

**MEMBERS**

**Mr. MILTON B. AMES, Jr.**, Office of Associate Administrator for Advanced Research and Technology, NASA

**Mr. WILLIAM H. WOODWARD**, Office of Associate Administrator for Advanced Research and Technology, NASA

**Dr. WALTON L. JONES**, Office of Associate Administrator for Advanced Research and Technology, NASA

**Mr. FRANK J. SULLIVAN**, Office of Associate Administrator for Advanced Research and Technology, NASA

**Capt. W. E. BEBB, USN**, Office of Naval Research, DOD

**Brig. Gen. EDWARD B. GILLER, USAF**, Director of Science and Technology, DOD

**Dr. GUILFORD G. QUARLES**, Office of Chief of Engineers, DOD

**Secretaries:** Lt. Col. EDWARD D. HARNEY, USAF, ODDR&E, DOD; Mr. REECE HENSLEY, Office of Associate Administrator for Advanced Research and Technology, NASA

**Alternates:** None desired

**UNMANNED SPACECRAFT PANEL**

**Chairman:** Mr. ROBERT F. GARBARINI, Deputy Associate Administrator for Space Science and Applications (Engineering), NASA

**Vice Chairman:** Mr. JOHN KIRK, Assistant Director (Space Technology), ODDR&E, DOD

**MEMBERS**

**Dr. JOHN E. NAUGLE**, Office of Associate Administrator for Space Science and Applications, NASA

**Mr. LEONARD JAFFE**, Office of Associate Administrator for Space Science and Applications, NASA

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**Mr. ORAN NICKS, Office of Associate Administrator for Space Science and Applications, NASA**

**Col. FRANCIS J. PALLISTER, USA, Office Chief of Research and Development, DOD**

**Capt. C. C. ANDREWS, USN, Astronautics Program Officer, Bureau of Naval Weapons, DOD**

**Brig. Gen. EDWARD B. GILLER, USAF, Director of Science and Technology, DOD**

**Secretaries: Capt. HOWARD SILBERSTEIN, USN, ODDR&E, DOD; Mr. JACK POSNER, Office of Associate Administrator for Space Science and Applications, NASA**

**Alternate: Mr. E. O. PEARSON, Office of Associate Administrator for Advanced Research and Technology, NASA; Col. CHESTER J. BUTCHER, USAF, Chief Space Plans Division, Directorate of Operational Requirements & Development Plans**

## Appendix D

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### NASA's Space Science Steering Committee

(December 31, 1965)

*Acting Chairman: JOHN E. NAUGLE  
Secretary: MARGARET B. BEACH*

#### MEMBERS

EDGAR M. COBRIGHT	JESSE L. MITCHELL
WILLIS B. FOSTER	HOMER E. NEWELL
ROBERT F. GARBARINI	ORAN W. NICKS
BENNY B. HALL	ORR E. REYNOLDS
LEONARD JAFFEE	HENRY J. SMITH
URNER LIDDEL	MORRIS TEPPER

#### ASTRONOMY SUBCOMMITTEE

*Chairman: NANCY G. ROMAN  
Secretary: ERNEST J. OTT*

#### MEMBERS

ALBERT BOGESS III, Goddard Space Flight Center
DAVID FISCHER, Ames Research Center
KARL GORDON HENIZE, Northwestern University
WILLIAM L. KRAUSHAAR, Massachusetts Institute of Technology
WILLIAM MARKOWITZ, U.S. Naval Observatory
NICHOLAS U. MAYALL, Kitt Peak National Observatory
GUIDO MUNCH, Mount Wilson and Palomar Observatory
EDWIN ERNEST SALPETER, Cornell University
ROBERT G. STONE, Goddard Space Flight Center

#### BIOSCIENCE SUBCOMMITTEE

*Chairman: ORR E. REYNOLDS  
Secretary: VIRGINIA B. BOLTON*

#### MEMBERS

ALLAN H. BROWN, University of Pennsylvania
LOREN D. CARLSON, University of Kentucky
SIDNEY FOX, University of Miami
JOHN DOUGLAS FRENCH, University of California
SIDNEY R. GALLER, Smithsonian Institution
GEORGE L. HOBBY, Jet Propulsion Laboratory
ELLIOTT LEVINTHAL, Stanford University
GERALD M. McDONNELL, University of California

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ERNEST C. POLLARD, Penn State University  
CARL SAGAN, Harvard University  
JAMES NEWELL STANNARD, University of Rochester  
WILLIAM G. STROUD, Goddard Space Flight Center  
ALGERNON G. SWAN, Brooks Air Force Base  
HANS-LUKAS TEUBER, Massachusetts Institute of Technology  
WOLF VISHNIAC, University of Rochester  
RICHARD S. YOUNG, Ames Research Center

### **IONOSPHERES AND RADIO PHYSICS SUBCOMMITTEE**

*Chairman:* ERWIN R. SCHMERLING  
*Secretary:* RAYMOND MILLER

#### **MEMBERS**

ARTHUR AIKEN, Goddard Space Flight Center  
KENNETH L. BOWLES, U.S. Commerce Department  
WYNN CALVERT, National Bureau of Standards  
OWEN K. GARBIOTT, Manned Spacecraft Center  
WILLIAM B. HANSON, Graduate Research Center of the Southwest  
ROBERT A. HELLIWELL, Stanford University  
JOHN E. JACKSON, Goddard Space Flight Center  
CHARLES Y. JOHNSON, Naval Research Laboratory  
EUGENE A. MECHTLY, Marshall Space Flight Center  
MILLETT GRANGER MORGAN, Dartmouth College  
THOMAS EDWARD VAN ZANDT, National Bureau of Standards

### **PARTICLES AND FIELDS SUBCOMMITTEE**

*Chairman:* ALOIS W. SCHARDT  
*Secretary:* ALBERT G. OPP

#### **MEMBERS**

KINSEY A. ANDERSON, University of California  
HERBERT SAGE BRIDGE, Massachusetts Institute of Technology  
LEVERETT DAVIS, Jr., California Institute of Technology  
WILMOT N. HESS, Goddard Space Flight Center  
ROBERT E. HOLZER, University of California  
CHRISTOPHER P. LEAVITT, University of New Mexico  
CARL EDWIN McILWAIN, University of California  
LESLIE MEREDITH, Goddard Space Flight Center  
NORMAN F. NESS, Goddard Space Flight Center  
JOHN ALEXANDER SIMPSON, University of Chicago  
CONWAY W. SNYDER, Jet Propulsion Laboratory  
PETER A. STURROCK, Stanford University  
WILLIAM R. WEBBER, University of Minnesota  
JOHN H. WOLFE, Ames Research Center

### **PLANETARY ATMOSPHERES SUBCOMMITTEE**

*Chairman:* ROBERT F. FELLOWS  
*Secretary:* HAROLD F. HIPSHER

**MEMBERS**

SIEGFRIED J. BAUER, Goddard Space Flight Center  
TALEBOT A. CHURB, Naval Research Laboratory  
RICHARD M. GOODY, Harvard University  
FRANK B. GRAY, Jet Propulsion Laboratory  
DONALD M. HUNTER, Kitt Peak National Observatory  
EDWARD C. Y. INN, Ames Research Center  
FRANCIS S. JOHNSON, Southwest Center for Advanced Studies  
WILLIAM W. KELLOGG, National Center for Atmospheric Research  
CHARLES GORDON LITTLE, National Bureau of Standards  
ALFRED O. C. NIER, University of Minnesota  
ANDREW E. POTTER, Lewis Research Center  
NELSON W. SPENCER, Goddard Space Flight Center

**PLANETOLOGY SUBCOMMITTEE**

*Chairman:* URNER LIDDEL  
*Secretary:* MARTIN W. MOLLOY

**MEMBERS**

RICHARD J. ALLENBY  
JAMES G. BECKERLEY, Radioptics, Inc.  
CHARLES L. CRITCHFIELD, University of California  
GEORGE B. FIELD, University of California  
CLARK D. GOODMAN, University of Houston  
JOHN SCOVILLE HALL, Lowell Observatory  
HARRY HAMMOND HESS, Princeton University  
GORDON J. F. MACDONALD, University of California  
ROBERT MEGHREMLIAN, Jet Propulsion Laboratory  
WILLIAM L. QUAIDE, Ames Research Center  
HARRISON SCHMIDT, Manned Spacecraft Center  
HAROLD C. UREY, University of California  
DONALD U. WISE, Franklin and Marshall College

**SOLAR PHYSICS SUBCOMMITTEE**

*Chairman:* HENRY J. SMITH  
*Secretary:* RICHARD E. HALPERN

**MEMBERS**

ROBERT DANIELSON, Princeton University  
MAURICE DUBIN, NASA  
WILLIAM ERICKSON, University of Maryland  
JOHN WAINWRIGHT EVANS, Jr., Sacramento Peak Observatory  
HERBERT FRIEDMAN, Naval Research Laboratory  
ROBERT HOWARD, Mount Wilson and Palomar Observatory  
WERNER M. NEUPEET, Goddard Space Flight Center  
GORDON NEWKIRK, High Altitude Observatory  
WILLIAM H. PARKINSON, Harvard College Observatory  
LAURENCE E. PETERSON, University of California  
WALTER ORB ROBERTS, National Center for Atmospheric Research

## **Appendix E**

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### **NASA's Historical Advisory Committee**

**(December 31, 1965)**

*Chairman:* MELVIN KRAZBERG, Case Institute of Technology

#### **MEMBERS**

LLOYD V. BERKNER, Graduate Research Center of the Southwest  
JAMES L. CATE, University of Chicago

A. HUNTER DUPREE, University of California (Berkeley)

WOOD GRAY, George Washington University

LAURENCE KAVANAU, North American Aviation, Inc.

MARVIN W. MCFARLAND, Library of Congress

PAUL A. VAN RIPER, Cornell University

ALAN T. WATERMAN, Former Director, National Science Foundation

*Executive Secretary:* EUGENE M. EMME, NASA Historian

## Appendix F

### Current Official Mailing Addresses for Field Installations

(December 31, 1965)

Installation and telephone number	Official	Address
Ames Research Center; 415-968-9411.	Dr. H. Julian Allen, Director.....	Moffett Field, Calif. 94035.
Electronics Research Center; 617-491-1500.	Dr. Winston E. Kock, Director.....	575 Technology Square, Cambridge, Mass. 02139.
Flight Research Center; 805-258-3311.	Mr. Paul Bikle, Director.....	Post Office Box 278, Edwards, Calif. 93321.
Goddard Space Flight Center; 301-474-4000.	Dr. John F. Clark, Acting Director.....	Greenbelt, Md. 20771.
Goddard Institute for Space Studies; 212-UN6-3600.	Dr. Robert Jastrow, Director.....	2880 Broadway, New York, N.Y. 10025.
Jet Propulsion Laboratory; 213-SY0-6811.	Mr. Earle J. Sample, Director.....	4800 Oak Grove Drive, Pasadena, Calif. 91103.
John F. Kennedy Space Center; 305-UL3-6998.	Dr. Kurt Debus, Director.....	Kennedy Space Center, Fla. 32890.
Langley Research Center; 703-722-7961.	Dr. Floyd L. Thompson, Director.....	Langley Station, Hampton, Va. 23365.
Lewis Research Center; 216-433-4000.	Dr. Abe Silverstein, Director.....	21000 Brookpark Road, Cleveland, Ohio 44135.
Manned Spacecraft Center; 713-WA8-2811.	Dr. R. R. Gilruth, Director.....	Houston, Tex. 77058.
George C. Marshall Space Flight Center; 205-877-1000.	Dr. Werner von Braun, Director.....	Huntsville, Ala. 35812.
Michoud Assembly Facility; 504-521-3311.	Dr. George N. Constan, Manager.....	Post Office Box 26078, New Orleans, La. 70126.
Mississippi Test Facility; 601-467-5466.	Mr. Jackson M. Balch, Manager.....	Bay St. Louis, Miss. 39520.
KSC Western Test Range Operations Division; 805-RE4-4311.	Mr. Joseph W. Schwartz, Acting Director.	Post Office Box 425, Lompac, Calif. 93438.
Plum Brook Station; 419-MA5-1123.	Mr. Alan D. Johnson, Director.....	Sandusky, Ohio. 44871.
Wallops Station; 703-VA4-3411.....	Mr. Robert Krieger, Director.....	Wallops Island, Va. 23337.
Western Operations Office; 213-EX3-9641.	Mr. R. W. Kamm, Director.....	150 Pico Blvd., Santa Monica, Calif. 90406.

## Appendix G

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### Principal NASA Officials at Washington Headquarters

(December 31, 1965)

JAMES E. WEBB-----	Administrator.
DR. HUGH L. DRYDEN*	Deputy Administrator.
BREEENE M. KERR-----	Assistant Administrator, Office of Technology Utilization and Policy Planning.
WALTER D. SOHIER-----	General Counsel.
ARNOLD W. FRUTKIN-----	Assistant Administrator, Office of International Affairs.
RICHARD L. CALLAGHAN-----	Assistant Administrator, Office of Legislative Affairs.
JULIAN SCHEER-----	Assistant Administrator, Office of Public Affairs.
DR. ROBERT C. SEAMANS, JR.-----	Associate Administrator.
EARL D. HILBURN-----	Deputy Associate Administrator.
JOHN D. YOUNG-----	Deputy Associate Administrator, Office of Administration.
WILLIAM B. RIEKE-----	Deputy Associate Administrator, Office of Industry Affairs.
DEMARQUIS D. WYATT-----	Deputy Associate Administrator, Office of Programing.
Adm. W. FRED BOONE, USN (Ret.)---	Deputy Associate Administrator, Office of Defense Affairs.
EDMOND C. BUCKLEY-----	Director, Office of Tracking and Data Acquisition.
DR. MAC C. ADAMS-----	Associate Administrator, Office of Advanced Research and Technology.
Dr. GEORGE E. MUELLER-----	Associate Administrator, Office of Manned Space Flight.
Dr. HOMER E. NEWELL-----	Associate Administrator, Office of Space Science and Applications.

(Telephone Information: 963-7101)

\*Deceased Dec. 1, 1965.

## **Appendix H**

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### **NASA's Inventions and Contributions Board**

**(December 31, 1965)**

<i>Chairman</i> .....	<b>ERNEST W. BRACKETT.</b>
<i>Vice Chairman</i> .....	<b>PAUL G. DEMBLING.</b>
<i>Executive Secretary</i> .....	<b>JAMES A. HOOTMAN.</b>
<i>Members</i> .....	<b>J. ALLEN CROCKER. C. GUY FERGUSON. ROBERT E. LITTELL. JOHN B. PARKINSON. ROBERT F. ALLNUTT.</b>

## Appendix I

### Patent Waivers Granted and Denied by NASA Upon Recommendation of the Agency's Inventions and Contributions Board

(July 1-December 31, 1965)

Invention	Petitioner	Action on petition
Divergent injector <sup>1</sup>	North American Aviation, Inc.	Denied.
Polyvinylene fluoride and copolymers <sup>1</sup>	Peninsular Chem Research, Inc.	Granted.
Process for the synthesis of 1,2-difluoroethylene <sup>1</sup>	do	Do.
Energy absorbing device <sup>1</sup>	Aerospace Research Associates	Do.
Process for the synthesis of perfluoro (methyl vinyl ether) $\text{CF}_3\text{OCF}=\text{CF}_2$ . <sup>1</sup>	Peninsular Chem Research, Inc.	Do.
Hollow filament forms for winding composite structures. <sup>1</sup>	DeBell and Richardson, Inc.	Do.
Solid filament forms for winding to form wound composite structures. <sup>1</sup>	do	Do.
Conical hydrostatic floating bearing <sup>1</sup>	Aerojet-General Corp.	Do.
Space suit water boiler with integrated control <sup>1</sup>	United Aircraft Corp.	Do.
Three-axis optical alinement unit <sup>1</sup>	North American Aviation, Inc.	Do.
Multipulse current driver <sup>1</sup>	Stanford Research Institute	Do.
Recording apparatus <sup>1</sup>	The Sperry Rand Corp.	Do.
Ring coupled mechanical filter <sup>1</sup>	Collins Radio Co.	Do.
Distributed constant pulse line <sup>1</sup>	General Dynamics/Astronautics	Do.
LOX "Safe" penetrant <sup>1</sup>	North American Aviation, Inc.	Do.
Apparatus and method for measuring total hemispherical emittance of a sample body. <sup>1</sup>	Arthur D. Little, Inc.	Do.
Vapor diffusion electrodes <sup>1</sup>	Monsanto Research Corp.	Do.
Palladium-coated plastic membranes for polarographic hydrogen sensors. <sup>1</sup>	Beckman Instruments, Inc.	Do.
Survival machete <sup>1</sup>	McDonnell Aircraft Corp.	Do.
Resolver controlled torquing system <sup>1</sup>	Bendix Corp.	Do.
Optical magnetometers and gradiometers <sup>1</sup>	Varian Associates	Do.
Optical magnetometers <sup>1</sup>	do	Do.
Turbopump arrangement <sup>1</sup>	United Aircraft Corp.	Do.
Scan converter feasibility study <sup>2</sup>	Litton Systems, Inc.	Denied.
Electrolytic oxygen generator <sup>1</sup>	Electrochimica Corp.	Granted.
An emission scattering photometer for particle size measurement. <sup>1</sup>	R. A. Dobbins (Brown University)	Do.
Widefield microscope with multiple inputs <sup>1</sup>	Farrand Optical Co.	Do.
Class waiver of all inventions to be made under Contract NAS 5-9518, relating to a memory device. <sup>2</sup>	The Sperry Rand Corp. (UNIVAC Division).	Do.
Improved silver-cadmium electrode <sup>1</sup>	Yardney Electric Corp.	Do.
Arc heater apparatus and heat shield assembly for use therein. <sup>1</sup>	Westinghouse Electric Corp.	Do.
Class waiver of all inventions to be made under Contract NAS 2-2486, relating to psychosensory responses. <sup>2</sup>	Bolt, Beranek & Newman, Inc.	Denied.
Blanket waiver to all inventions arising out of Contract NAS 5-9106, relating to improving the performance characteristics and reliability of silver-cadmium cells. <sup>2</sup>	Yardney Electric Corp.	Granted.

See footnotes at end of table.

Invention	Petitioner	Action on petition
Blanket waiver to all inventions arising out of Contract NAS 9-3699 relating to improvements in positive carbon electrodes. <sup>2</sup>	Union Carbide Corp.....	Do.
Blanket waiver to all inventions arising out of Contract NAS 3-6465 and relating to magnetic and electrical materials. <sup>2</sup>	Westinghouse Electric Corp.....	Do.
Fluid binary counter <sup>1</sup> .....	Sperry Rand Corp.....	Do.
Five-state fluid logic element <sup>1</sup> .....	do.....	Do.
Fluid shift register <sup>1</sup> .....	do.....	Do.

<sup>1</sup> Invention waiver.

<sup>2</sup> Blanket waiver.

## Appendix J

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### SCIENTIFIC AND TECHNICAL CONTRIBUTIONS RECOGNIZED BY THE AGENCY'S INVENTIONS AND CONTRIBUTIONS BOARD

(July 1-December 31, 1965)

#### Awards Granted Under Provisions of Section 306 of the Space Act of 1958

Contribution	Inventor(s)	Employer
Heat Insulator.....	Casimir F. Kubik.....	North American Aviation, Inc.
Electric arc apparatus.....	Howard A. Stine, Charles E. Shepard, Velvin R. Watson.	Ames Research Center.

## Appendix K

### Awards Granted NASA Employees Under Provisions of the Incentive Awards Act of 1954

(July 1-December 31, 1965)

Contribution	Inventor(s)	Employer
Three axis flight vehicle attitude controller.	Euclid C. Holleman.....	Flight Research Center.
Foamed-in-place ceramic refractory insulating material.	A. Guy Eubanks, Ronald E. Hunkele.....	Goddard Space Flight Center.
Variable time constant smoothing circuit.	Raymond George Hartenstein.....	Do.
Folding boom assembly.....	John P. Baumereschub, Jr.....	Do.
Digital telemetry system.....	Majorie R. Townsend, Paul M. Feinberg.....	Do.
Amplifier clamping circuit.....	Clarence Cantor.....	Do.
Electron beam switching commutator.....	Philip A. Studer.....	Do.
Method and apparatus for phase stability measurement of a high-frequency signal source.	Grady B. Nichols.....	Do.
A method of matching complex impedances.	Richard F. Schmidt.....	Do.
Conforming polisher for aspheric surfaces of revolution.	William J. Hungerford, John W. Larmer, Maurice Levinsohn.....	Do.
Bonded elastomeric seal for electrochemical cells.	Joseph M. Sherley.....	Do.
Hypersonic reentry vehicle.....	Edward E. Mayo.....	Do.
Spacecraft.....	Robert H. Lamb.....	Manned Spacecraft Center.
Valve seat.....	Edward E. Mayo.....	Goddard Space Flight Center.
Fused diode.....	Robert H. Lamb.....	Manned Spacecraft Center.
Attitude sensor for space vehicles.....	Elvis D. Wallace.....	J. F. Kennedy Space Center.
Multilegged support system.....	Keith H. Jenkins.....	Do.
Image intensifier tube.....	Norman M. Hatcher.....	Langley Research Center.
Manned space station.....	Weymouth B. Crumpler.....	Do.
Fatigue testing device.....	Clinton E. Brown, Jack W. Crenshaw.....	Do.
Heat sensing instrument.....	Emanuel Schnitzer.....	Do.
Electrical connector.....	Eugene C. Naumann, Emmett Lewis Bryant.....	Do.
Attitude control and damping system for spacecraft.	Howard B. Miller, William D. Harvey.....	Do.
Solar sensor.....	Howard B. Miller.....	Do.
Control system for rocket vehicles.....	Peter R. Kurzhals, Ralph W. Will.....	Do.
Air frame drag balance.....	Anthony Fontana.....	Do.
	Norman L. Crabill, John M. Riebe.....	Do.
	Abraham Leiss, Joseph Judd, Robert S. Freeman.....	Do.

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Contribution	Inventor(s)	Employer
Thermal control coating.....	Noel T. Wakelyn.....	Langley Research Center.
Impact energy absorber.....	Ira S. Hoffman, Thomas Vranas.....	Do.
An omnidirectional microwave space-craft antenna.....	William F. Croswell, Melvin C. Gilreath.....	Do.
All-directional fastener.....	Weymouth B. Crumpler.....	Do.
Viscous-pendulum-damper.....	Wilmer H. Reed III.....	Do.
Ablation sensor.....	Clifford H. Nelson, Charles A. Gurtler.....	Do.
Vehicle thrust and direction control apparatus.....	Robert W. Cubbison, James F. Connors.....	Lewis Research Center.
An electrostatic ion rocket engine.....	Paul D. Reader, Harold R. Kaufman.....	Do.
An insulation system.....	Porter J. Perkins, Jr.....	Do.
Gas purged dry box glove.....	Gustav Reinhardt, Max Quatinetz, Thomas P. Herbell.....	Do.
Analytical test apparatus and method therefor.	Judson W. Graab, Randall F. Gahn, Louis Rosenblum, William E. Maple, William A. Dupraw.....	Do.
Electrode for biological recording.....	Joe L. Day, Maxwell W. Lippitt, Jr.....	Manned Spacecraft Center.
Mass measuring systems.....	William L. Green, Richard W. Bricker.....	Do.
Voltage-current characteristic simulator for photovoltaic panels.....	Jerome H. Grayson.....	Do.
Electrode paste.....	Maxwell W. Lippett, Jr., Joe L. Day.....	Do.
Radiation detector readout system.....	Kenneth D. Cashion, Benny R. Baker.....	Do.
Ion-exchange membrane and electrode assembly.....	Hoyt McBryar, Herschel H. Jamison.....	Do.
Training vehicle for controlling attitude.....	Harold I. Johnson.....	Do.
Multiple-environment materials test chamber.....	Robert L. Johnston.....	Do.
Ablation structures.....	Andre J. Meyer, Jr.....	Do.
Centrifuge type dip, spin, and sling method for coating the circuit paths of printed circuit boards.....	Albin E. Wittmann.....	Marshall Space Flight Center.
Spherical balloon wind sensor.....	James R. Scoggins.....	Do.
Fluid transporting system.....	Dolphus H. Black.....	Do.
Device and method for suppressing sound and heat produced by high-velocity exhaust jets.....	Fritz Kramer.....	Do.
Connector fitting with locking means.....	Claude J. Bowen.....	Do.
Gimbaled, partially submerged rocket.....	Richard L. Brown.....	Do.
Azimuth laying system.....	Herman E. Thomason, Carl H. Mandel.....	Do.
Multimission module.....	Jay H. Laue.....	Do.
Three-wire receptical testing instrument.....	James B. Huff.....	Do.
Positive displacement flowmeter.....	Frederic E. Wells.....	Do.
Fiber optic vibration transducer and analyzer.....	Alonza J. Davis.....	Do.
Vacuum apparatus.....	Robert J. Carmody.....	Do.
Fluid flow sensor.....	James R. Scoggins.....	Do.
Apparatus and method for making precision circular spot recesses.....	William J. Abernathy, William J. Reed, Lowell G. Snoddy, John R. Sealy.....	Do.
Fine adjustment device.....	Wilhelm Angele, Donelson B. Horton.....	Do.

## Appendix L

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### Educational Publications and Motion Pictures

(December 31, 1965)

During the last 6 months of 1965 NASA released the following new educational publications which are available to the public without charge from the Media Development Division, Code FAD-1, National Aeronautics and Space Administration, Washington, D.C. 20546. Other educational publications are listed in a brochure supplied from the same address.

#### Booklets and Folders

*A Walk in Space*.—An illustrated account of Astronaut White's "space walk" during the flight of Gemini IV in June 1965. 24 pp.

*Space Exploration—Why and How*.—The booklet asks "why explore space," provides some answers, and describes the goals and achievements of NASA's programs. 20 pp.

*Meteorological Satellites and Sounding Rockets*.—A description of the Nation's programs to provide more accurate weather forecasts and increase the knowledge of the complex processes that make the weather. Included are work done with the TIROS and Nimbus weather satellites, and with meteorological sounding rockets, and plans for future advanced systems. 24 pp.

*Space and the International Cooperation Year: A National Challenge*.—NASA's Assistant Administrator for International Affairs describes the U.S. program of cooperation with other nations in the peaceful exploration and use of space. 19 pp.

*Historical Sketch of NASA*.—An account of the origin and development of the National Aeronautics and Space Administration by the Agency's historical staff. 56 pp.

#### NASA Facts

Describes NASA programs, with photographs and diagrams of spacecraft and launch vehicles. Sheets are designed for bulletin board display or for insertion in looseleaf notebooks.

*Pegasus*.—Describes NASA's satellites to acquire more information about meteoroids, and tells briefly what has been learned from previous meteoroid studies. 8 pp.

*Manned Space Flight: Project Apollo*.—A brief account of the Nation's program to land American explorers on the moon and return them to earth during this decade. 12 pp.

#### Motion Pictures

NASA released these five new motion pictures during July through December 1965. They may be borrowed—without charge other than return mailing and insurance costs—from the Media Development Division, Code FAD-2, National Aeronautics and Space Administration, Washington, D.C. 20546. (Other films are listed in a brochure supplied from the same address.)

*The Case for Regeneration.*—12 min., sound, color. Part I in a series of films on "Living In Space." Shows why oxygen and water needed to support life must be recovered from an astronaut's bodily wastes, how freeze-dried foods are reconstituted, and the principal features that must be incorporated in a closed regenerative system to keep men in comfort and good health during space flights of several months or years.

*Regenerative Processes.*—22 min., sound, color. Part II in the "Living In Space" series. The physics, chemistry, and mechanics involved in a closed regenerative life-support system to maintain men in space for long periods of time and the general operating characteristics of a prototype system built and installed at the Langley Research Center.

*A Technology for Spacecraft Design.*—12 min., sound, color. Part III of "Living In Space." The technology being developed to enable scientists and engineers to design and build a flyable regenerative life-support system for manned space missions lasting months or years.

*Men Encounter Mars.*—28½ min., sound, black and white, 16 mm. A behind-the-scenes documentary about the engineers and scientists who planned and directed Mariner IV's complex mission to photograph the Martian surface, and the story of their teamwork which resulted in the first pictures of the Red Planet in July 1965.

*The Four Days of Gemini IV.*—28 min., sound, color. Produced by the Manned Spacecraft Center. The Gemini IV flight of Astronauts McDivitt and White in June 1965. Includes color sequences of prelaunch and launch activities, White's "space walk," and other experiments conducted during the mission. The film also shows the preflight training of McDivitt and White, and takes a detailed look at White's suit worn outside the Gemini spacecraft and his "space gun."

## **Appendix M**

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### **Technical Publications**

**(July 1—December 31, 1965)**

The following selected special publications, issued by NASA's Scientific and Technical Information Division, are sold by the Superintendent of Documents, U.S. Government Printing Office (GPO), Washington, D.C. 20402, or by the Clearinghouse for Federal Scientific and Technical Information (CFSTI), Springfield, Va. 22151, at the prices listed.

*NASA Conference on Aircraft Operating Problems* (NASA SP-83).<sup>1</sup>—The published papers of a conference at Langley Research Center, May 10-12, 1965. 327 pp. CFSTI, \$3.

*Proceedings of Second Symposium on Protection Against Radiations in Space* (NASA SP-71).<sup>1</sup>—Published papers of a conference held at Gatlinburg, Tenn., October 1964, and sponsored by AEC, NASA, and USAF. Four disciplines are represented: The Radiation Environment, Biological Effects, Effects on Materials, and Shielding. 551 pp. GPO, \$3.25.

*Proceedings of the Apollo Unified S-Band Technical Conference* (NASA SP-87).<sup>1</sup>—Presentations at a conference at Goddard Space Flight Center, July 14-15, 1965, describing the ground systems that Goddard is now implementing in support of the Apollo Manned Space Flight Network. 302 pp. CFSTI, \$3.

*Ranger VII Photographs of the Moon. Part III: Camera "P" Series* (NASA SP-63).<sup>1</sup>—The third and last volume of Ranger VII photos of the moon. Part III includes 758 of the more than 3,900 photographs taken with the four partial-scan "P" cameras. 200 pp. GPO, \$6.50.

*NASA-University Program Review Conference* (NASA SP-85).<sup>1</sup>—The report of a conference in Kansas City, March 2-4, 1965, on the work sponsored by NASA through its grants and research contracts program. 400 pp. GPO, \$1.50.

*Final Report on the Relay I Program* (NASA SP-76).<sup>1</sup>—A report dealing with design, development, and performance of the spacecraft hardware; the communications and radiation experiments; and a description of the Nutley, N.J., and Andover, Maine, ground stations. In addition, the report contains all the information received from foreign governments participating in the Relay I project. 768 pp. GPO, \$4.25.

*Dictionary of Technical Terms for Aerospace Use* (NASA SP-7).<sup>1</sup>—This first edition of the NASA dictionary gives precise definitions of more than 6,000 terms frequently used by space scientists and technologists. 314 pp. GPO, \$3.

*NASA 1965 Summer Conference on Lunar Exploration and Science* (NASA SP-88).<sup>1</sup>—A document presenting results of the Falmouth, Mass., conference on

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<sup>1</sup> Released during this report period.

lunar exploration, with the conclusions and recommendations of the people responsible for planning the lunar phase of space exploration. 422 pp. GPO, \$1.50.

*Observations From the Nimbus I Meteorological Satellite* (NASA SP-89).<sup>1</sup>—Discussions of early results obtained with the Nimbus I satellite. 90 pp. CFSTI, \$1.

*Astronautics and Aeronautics, 1964: Chronology on Science, Technology, and Policy* (NASA SP-4005).<sup>1</sup>—A chronology of events and statements of the seventh year of the space age compiled from open public sources. 528 pp. GPO, \$1.75.

*Space Medicine in Project Mercury* (NASA SP-4003).<sup>1</sup>—This volume examines the development of NASA's fund of space medicine information and experience and shows how the Agency was able to draw upon the resources of the Air Force, the Navy, other Government agencies, industry, and academic and private research institutions to develop life-support systems to protect man against the stresses of launch, orbit, reentry, and impact. 198 pp. GPO, \$1.

*Aerodynamic Design of Axial-Flow Compressors* (NASA SP-36).—Results of the extensive research on the design of axial-flow compressors, formerly scattered, have been assimilated and correlated in this volume. Attention has been focussed primarily on the problems pertinent to the axial-flow compressors of turbojet or turboprop engines, but the results should be applicable to any class of axial-flow compressors. 508 pp. GPO, \$3.

*Explorer VI* (NASA SP-54).—This volume contains selected papers and reports on data collected by Explorer VI which was designed to provide a co-ordinated, comprehensive group of measurements of scientific interest over as large a region of the magnetosphere as possible. Simultaneous studies were made of the trapped radiation in the Van Allen region, galactic cosmic rays, geomagnetism, radio propagation in the upper atmosphere, and the flux of micrometeorites of cosmic dust. 381 pp. GPO, \$2.25.

*X-15 Research Results With a Selected Bibliography* (NASA SP-60).—A semitechnical summary of the X-15 program directed toward the achievements in scientific research rather than toward the better-publicized and spectacular milestones of flight in the near-space environment. The book traces the history of the joint NASA-Air Force-Navy program from the early hypersonic flight studies by NACA through the first 120 flights of the 3 rocket-powered research airplanes. 128 pp. GPO, 55 cents.

*Ranger VII Photographs of the Moon. Part II: Camera "B" Series* (NASA SP-62).—Reproduction of the 200 photos from the "B" camera. The "B" camera, with an f/2 lens of 38-mm. aperture and 76-mm. focal length, and a detector of the same dimension as the "A" camera, had a field of 8.4 x 8.4. 217 pp. GPO, \$6.50.

*Proceedings of the Conference on Space Nutrition and Related Waste Problems* (NASA SP-70).—The proceedings of a conference held in April 1964 at which Government, industry, and university scientists considered the nutrition and waste problems associated with maintaining astronauts in space, especially over extended periods of time. Approximately 60 papers with discussions by conferees. 400 pp. GPO, \$2.75.

*NASA Symposium on the Analysis of Central Nervous System and Cardiovascular Data Using Computer Methods* (NASA SP-72).—A conference at which Government and university authorities discussed the use of computer techniques in collecting and analyzing data on the central nervous and cardiovascular systems. 600 pp. CFSTI, \$4.50.

<sup>1</sup> Released during this report period.

*Electrical Power Generation Systems for Space Applications* (NASA SP-79).—A state-of-the-art summary of several papers and committee reports on electric-power generation systems for space application, prepared by the Department of Defense and NASA for the Supporting Research and Technical Panel of the Aeronautics and Astronautics Coordinating Board. 40 pp. CFSTI, \$1.

*Bioastronautics Data Book* (NASA SP-3006).—This book is for designers of aerospace vehicles and equipment. It contains carefully selected applied research data from the life sciences in consistent engineering units accompanied by metric scales. 400 pp. GPO, \$2.25.

*Astronautics and Aeronautics, 1963: Chronology on Science, Technology, and Policy* (NASA SP-4004).—A chronology of the significant aerospace events for the year 1963 compiled by the NASA Historical Staff. 610 pp. GPO, \$2.

*Physics of Nonthermal Radio Sources* (NASA SP-46).—Proceedings of a conference for an international group of astronomers and physicists held December 3-4, 1962 at the NASA Goddard Institute for Space Studies. The papers cover radio observations, optical observations, and theory of nonthermal radio sources outside the solar system. 171 pp. GPO, 75 cents.

*AAS-NASA Symposium on the Physics of Solar Flares* (NASA SP-50).—The published proceedings of a conference of American, European, Asian, and Australian scientists reporting on research progress in the field of solar flare activity. 466 pp. GPO, \$3.25.

*Proceedings of the Fourth National Conference on the Peaceful Uses of Space* (NASA SP-51).—Thirty papers delivered at the Conference held in Boston, April 29 to May 1, 1964. Six sessions: Space and the Nation, Congress and Science, Men in Space, Machines in Space, Practical Uses of Satellites, Living in Space, and Working for Space. 226 pp. GPO, \$1.50.

*Quasi-Global Presentation of TIROS III Radiation Data* (NASA SP-53).—Explanatory text, illustrations, and colored maps of the reflected solar radiation of the earth-atmosphere system on July 16, 1961, superimposed on various synoptic analyses to study the utility of the satellite radiation data for purposes of meteorological analysis. 24 pp. GPO, \$2.

*Concepts for Detection of Extraterrestrial Life* (NASA SP-56).—The devices and instruments described in this illustrated booklet are among those planned for inclusion in vehicles designed to land on planets such as Mars. They constitute techniques for detecting growth and metabolism, for determining the presence of biologically significant molecules and for actual visual observation of micro-organisms and the planetary terrain. 54 pp. GPO, 50 cents.

*Ranger VII Photographs of the Moon. Part I: Camera "A" Series* (NASA SP-61).—Reproduction of the 199 photographs taken by the "A" camera of Ranger VII from 1,300 to 3 miles above the surface of the moon. 266 pp. GPO, \$6.50.

*Clarity in Technical Reporting* (NASA SP-7010).—Basic principles of technical reporting designed to guide engineers and scientists in improving the general quality of written and oral reports. 25 pp. GPO, 15 cents.

*The International System of Units—Physical Constants and Conversion Factors* (NASA SP-7012).—This document gives definitions of the basic units of the Système International, adopted officially by the 1960 11th General Conference on Weights and Measures, and tables for converting from U.S. Customary Units. 20 pp. GPO, 20 cents.

*Advanced Bearing Technology* (NASA SP-38).—An exposition of the fundamentals of friction and wear, fluid-film bearings, and rolling-element bearings,

plus demonstrations of how fundamental principles can be applied to the solution of unique and advanced bearing problems. Authors, Edmond E. Bisson and William J. Anderson, Lewis Research Center. 511 pp. GPO, \$1.75.

*Conference on the Law of Space and of Satellite Communications* (NASA SP-44).—Proceedings of a conference organized by Northwestern University School of Law, May 1-2, 1963, as part of the Third National Conference on the Peaceful Uses of Space. 205 pp. GPO, \$1.50.

*Space-Cabin Atmospheres. Part I: Oxygen Toxicity* (NASA SP-47).—A review of the literature on toxicity of oxygen at pressures of less than 1 atmosphere and the relation of oxygen to other factors of concern in space cabins such as radiation effects and lung blast. 51 pp. GPO, 40 cents.

*Space-Cabin Atmospheres. Part II: Fire and Blast Hazards* (NASA SP-48).—A summary of the open literature on the subject intended primarily for biomedical scientists and design engineers. 119 pp. GPO, \$1.

*Meteorological Observations Above 30 Kilometers* (NASA SP-49).—Three papers on meteorological rockets, network data, and rocket soundings comprising one session of a conference on Meteorological Support for Aerospace Testing and Operation, July 11-12, 1963, 57 pp. GPO, 40 cents.

*Project Mercury Summary Including Results of the Fourth Manned Orbital Flight, May 15 and 16, 1963* (NASA SP-45).—A review of the planning, preparation, experiences, and results of the U.S. manned space flight program with particular attention to the results of the final, 34-hour mission of Astronaut L. Gordon Cooper. 444 pp. GPO, \$2.75.

*Second U.S. Manned Orbital Space Flight* (NASA SP-6).—Results of the MA-7 flight by Astronaut M. Scott Carpenter, May 1962, including spacecraft and launch-vehicle performance, Mercury network performance, mission operations, space science report, aeromedical studies, pilot performance, and pilot's flight report. 107 pp. GPO, 65 cents.

*Third U.S. Manned Orbital Space Flight* (NASA SP-12).—Results of the MA-8 flight by Astronaut Walter Schirra, October 1962, including spacecraft and launch-vehicle performance, mission operations, aeromedical analysis, pilot performance, and pilot's flight report. 120 pp. GPO, 70 cents.

*Project Mercury—A Chronology* (NASA SP-4001).—A listing of major events in the first U.S. manned space flight program from preliminary discussions of earth satellite vehicles through Astronaut Cooper's 22-orbit flight, May 1963. 238 pp. GPO, \$1.50.

*Results of the Project Mercury Ballistic and Orbital Chimpanzee Flights* (NASA SP-39).—An account of the suborbital and orbital flights conducted in 1961 with chimpanzees as subjects in preparation for the first U.S. manned space flight. 71 pp. GPO, 45 cents.

*Space, Science, and Urban Life* (NASA SP-37).—Proceedings of a conference, March 1963, on the applicability of the national space program, and the knowledge resulting from aerospace research, to the problems of urban growth. 254 pp. GPO, \$1.75.

*The Observatory Generation of Satellites* (NASA SP-30).—Discussion of the missions and engineering designs of the Orbiting Geophysical Observatories, the Advanced Orbiting Solar Observatory, and the Orbiting Astronomical Observatory. 62 pp. GPO, 50 cents.

*Ariel I: The First International Satellite* (NASA SP-43).—Project summary of the satellite launched April 26, 1962 in a cooperative effort by the United Kingdom and the United States. 76 pp. GPO, 70 cents.

*U.S. Standard Atmosphere, 1962.*—Updated tables of atmospheric parameters to 700 kilometers incorporating results of rocket and satellite research through mid-1962. 278 pp., in hard covers. GPO, \$3.50.

*Short Glossary of Space Terms* (NASA SP-1).—Brief definitions of technical terms frequently used by space technologists. 57 pp. GPO, 25 cents.

*NASA-Industry Program Plans Conference, 1963* (NASA SP-29).—Statements describing NASA's organization, present plans, and possible future projects presented for the information of industrial management as a partner in the national space program. 231 pp. GPO, \$1.25.

*Measurement of Thermal Radiation Properties of Solids* (NASA SP-31).—Proceedings of a symposium sponsored jointly by NASA, the Air Force, and the National Bureau of Standards. 587 pp. GPO, \$3.50.

*Proceedings of the NASA-University Conference on the Science and Technology of Space Exploration, Chicago, Ill., November 1962* (NASA SP-11)—

Volume 1: NASA's role in space exploration; developing special skills for research in the space sciences; impact of the space program on the universities; the role of the university in meeting national goals in space exploration; radar astronomy; the sounding rocket as a tool for college and university research; geophysics and astronomy; lunar and planetary sciences; celestial mechanics and space flight analysis; data acquisition and processing; control, guidance, and navigation; bioastronautics. 429 pp. GPO, \$2.50.

Volume 2: Chemical rocket propulsion; nuclear propulsion; power for spacecraft; electric propulsion; aerodynamics; gas dynamics; plasma physics and magnetohydrodynamics; laboratory techniques; materials; structures. 532 pp. GPO, \$3.

The scientific papers presented at the conference, grouped by topics, are also available as separate state-of-the-art summaries:

	Cents
Geophysics and Astronomy in Space Exploration (NASA SP-13)-----	35
Lunar and Planetary Sciences in Space Exploration (NASA SP-14)-----	55
Celestial Mechanics and Space Flight Analysis (NASA SP-15)-----	35
Data Acquisition from Spacecraft (NASA SP-16)-----	40
Control, Guidance and Navigation of Spacecraft (NASA SP-17)-----	40
Chemical Rocket Propulsion (NASA SP-19)-----	40
Nuclear Rocket Propulsion (NASA SP-20)-----	45
Power for Spacecraft (NASA SP-21)-----	25
Electric Propulsion for Spacecraft (NASA SP-22)-----	35
Aerodynamics of Space Vehicles (NASA SP-23)-----	40
Gas Dynamics in Space Exploration (NASA SP-24)-----	40
Plasma Physics and Magnetohydrodynamics in Space Exploration (NASA SP-25)-----	50
Laboratory Techniques in Space Environment Research (NASA SP-26)-----	40
Materials for Space Operations (NASA SP-27)-----	35
Structures for Space Operations (NASA SP-28)-----	35

*A Technique for Joining and Sealing Dissimilar Materials* (NASA SP-5016).<sup>1</sup>—A report describing a boltless attachment and sealing method conceived and used during low-temperature research at NASA's Lewis Research Center. 8 pp. CFSTI, 25 cents.

<sup>1</sup> Released during this report period.

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*Technical and Economic Status of Magnesium-Lithium Alloys* (NASA SP-5028).<sup>1</sup>—A report on general characteristics, current applications, and economic considerations for future use of the magnesium-lithium alloys. 45 pp. GPO, 25 cents.

*Medical and Biological Applications of Space Telemetry* (NASA SP-5023).<sup>1</sup>—A report on the biotelemetry systems developed for or employed in the space effort and in civilian biomedical applications. 66 pp. GPO, 45 cents.

*Metal-Forming Techniques* (NASA SP-5017).<sup>1</sup>—A report outlining present metal-forming methods for sheet and plate materials used by the aircraft and aerospace industries, as well as experimental methods such as magnetic forming and hot-drape forming. 52 pp. GPO, 40 cents.

*Plasma Jet Technology* (NASA SP-5033).<sup>1</sup>—A survey emphasizing the industrial potential of plasma generators in materials testing, coating, and spraying, chemical synthesis, and other industrial operations. 200 pp. GPO, \$1.

*Handling Hazardous Materials* (NASA SP-5032).<sup>1</sup>—Methods for safe handling of highly reactive materials (such as liquid hydrogen, pentaborane, fluorine, and hydrazine) are surveyed in relation to their hazardous properties. 96 pp. GPO, 45 cents.

*Elastic Orifices for Gas Bearing* (NASA SP-5029).<sup>1</sup>—A report describing an elastic orifice for the control of fluid flow in a pressurized gas bearing. 12 pp. GPO, 20 cents.

*Selected Shop Techniques* (NASA SP-5010).<sup>1</sup>—A handbook prepared especially for machinists, mechanics, and those working in related crafts. The techniques depicted show how fabrication obstacles were overcome by improvisation, by creating new tools, and by applying old and maybe "all-but-forgotten" techniques to new fields. 102 pp. GPO, 60 cents.

*Tungsten Powder Metallurgy* (NASA SP-5035).<sup>1</sup>—A report summarizing recent developments in tungsten powder metallurgy technology as related to space vehicles and the less traditional applications. 40 pp. GPO, 35 cents.

*Microelectronics in Space Research* (NASA SP-5031).<sup>1</sup>—A survey, the primary purpose of which is to provide information on the contributions to the microelectronics field that have originated in NASA research programs. 130 pp. GPO, 60 cents.

*The Electromagnetic Hammer* (NASA SP-5034).<sup>1</sup>—A report describing a method, being investigated at George C. Marshall Space Flight Center and by NASA contractors, of using electromagnetic forces for removing the distortion from welded components. 22 pp. GPO, 25 cents.

*Advanced Valve Technology* (NASA SP-5019)—This book identifies present limitations of commercially available valves, and recognizes current technological advancements beyond the general state-of-the-art industry. Present valve problem areas are recognized, research and development activities in these areas discussed, and the newer trends and techniques reported. 181 pp. CFSTI, \$5.

*Micropower Logic Circuits* (NASA SP-5022).—Illustrated descriptions of a number of digital logic circuits that were developed primarily to fill a need for very low-power logic systems in space vehicles but which can easily be adapted for specific applications in nonspace computer systems. 15 pp. CFSTI, 75 cents.

*Measurement of the Heartbeat of Bird Embryos with a Micrometeorite Transducer* (NASA SP-5007).—Description of a device consisting of a pair of piezoelectric beams arranged to serve as springs and acceleration detectors, originally designed to serve as a detector of the impact of meteorites on spacecraft and satellites. 10 pp. CFSTI, 50 cents.

<sup>1</sup> Released during this report period.

*Selected Welding Techniques, Part II* (NASA SP-5009).—Outlines some of the more recent and interesting technological developments in welding. Welding tools and techniques described were selected from those used in welding aluminum sheet and plate at NASA's George C. Marshall Space Flight Center. 34 pp. GPO, 30 cents.

*Effects of Low Temperatures on Structural Metals* (NASA SP-5012).—Data developed by NASA's George C. Marshall Space Flight Center during inhouse and contractor research on the properties of materials at low temperatures. 55 pp. GPO, 40 cents.

*Precision Tooling Techniques* (NASA SP-5013).—A description of novel tooling techniques with possible industrial applications developed at NASA's George C. Marshall Space Flight Center. 25 pp. GPO, 25 cents.

*NASA Contributions to the Technology of Inorganic Coatings* (NASA SP-5014).—A survey of NASA's contributions in the areas of thermophototropic coatings, thermal control coatings for space vehicles, solid lubrication coatings, thermal insulation coatings, application of coatings to substrates, measurement of coating optical properties, and refractory metal oxidation-resistant coatings. 268 pp. GPO, \$1.

*Conference on New Technology* (NASA SP-5015).—Proceedings of a conference on technology utilization held to discuss ways of transferring applicable space research knowledge to the industrial community. 156 pp. GPO, \$1.

*Selected Welding Techniques* (NASA SP-5003).—Descriptions and illustrations of tools and methods developed by NASA, and of potential value to industry, for welding aluminum sheet and plate. 25 pp. GPO, 30 cents.

*Space Batteries* (NASA SP-5004).—Descriptions of three-sealed battery systems for spacecraft, including discussion of a mechanism of information exchange whereby current test data can be shared among space contractors. 53 pp. GPO, 25 cents.

*The Measurement of Blood Pressure in the Human Body* (NASA SP-5006).—A state-of-the-art summary prepared from the open literature for nonmedical scientists and engineers. 34 pp. GPO, 30 cents.

A comparatively new subseries of special publications consisting of compilations and handbooks that present engineering and scientific information in conveniently useful form for those working in specific fields, saving them time-consuming searches to assemble these data. Among these publications are:

*Charts for Approximate Thermodynamic Properties of Nitrogen-Oxygen Mixtures* (NASA SP-3017).<sup>1</sup> 116 pp. CFSTI, \$1.25.

*Charts for Equilibrium and Frozen Flows Across Plane Shock Waves in Carbon Dioxide* (NASA SP-3018).<sup>1</sup> 129 pp. CFSTI, \$1.

*Charts for Equilibrium and Frozen Nozzle Flows of Carbon Dioxide* (NASA SP-3019).<sup>1</sup> 78 pp. CFSTI, 75 cents.

*Charts of Isentropic Exponent as a Function of Enthalpy for Various Gases in Equilibrium* (NASA SP-3020).<sup>1</sup> 10 pp. CFSTI, 50 cents.

*Equilibrium Thermodynamic Properties of Three Engineering Models of the Martian Atmosphere* (NASA SP-3021).<sup>1</sup> 162 pp. CFSTI, \$2.50.

*Magnetic Fields Due to Solid and Hollow Conical Conductors* (NASA SP-3022).<sup>1</sup> 132 pp. CFSTI, \$1.

*Tables of Energy Losses and Ranges of Electrons and Positrons* (NASA SP-3012). 127 pp. CFSTI, \$4.

*Tables of Energy Losses and Ranges of Heavy Charged Particles* (NASA SP-3013). 131 pp. CFSTI, \$4.

<sup>1</sup> Released during this report period.

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*Equilibrium Thermodynamics Properties of Carbon Dioxide* (NASA SP-3014). 66 pp. CFSTI, \$3.

*Charts for Equilibrium Flow Properties of Carbon Dioxide in Hypervelocity Nozzles* (NASA SP-3015). 71 pp. CFSTI, \$3.

*Venus and Mars Nominal Natural Environment for Advanced Manned Planetary Mission Programs* (NASA SP-3016). 48 pp. CFSTI, \$2.

*Tables for Supersonic Flow Around Right Circular Cones at Small Angle of Attack* (NASA SP-3007). 422 pp. GPO, \$2.25.

*Tables of the Complex Fresnel Integral* (NASA SP-3010). 294 pp. CFSTI, \$4.

*Thermodynamic and Transport Properties for the Hydrogen-Oxygen System* (NASA SP-3011). 419 pp. CFSTI, \$6.

*Thermodynamic Properties and Mollier Chart for Hydrogen from 300° to 20,000° K.* (NASA SP-3002). 64 pp. CFSTI, \$1.75.

*Tables for Supersonic Flow Around Right Circular Cones at Zero Angle of Attack* (NASA SP-3004). 422 pp. GPO, \$2.25.

*Energy Spectra and Angular Distributions of Electrons Transmitted Through Sapphire ( $\text{Al}_2\text{O}_3$ ) Foils* (NASA SP-3008). 108 pp. CFSTI, \$2.50.

*Tables of the Composition, Opacity, and Thermodynamic Properties of Hydrogen at High Temperatures* (NASA SP-3005). 186 pp. CFSTI, \$3.

*Tables of Flow Properties of Thermally Perfect Carbon Dioxide and Nitrogen Mixtures* (NASA SP-3009). 114 pp. CFSTI, \$4.50.

## Appendix N

### Major NASA Launches

(July 1-December 31, 1965)

Name, date launched, mission	Vehicle	Site <sup>1</sup>	Results
TIROS X, July 2 Meteorological satellite to provide hurricane coverage during the 1965 hurricane season.	Delta	ETR	Attained nearly circular orbit. Transmitted useful data and cloud cover photographs. (Apogee—520.087 miles; Perigee—462.92 miles.)
Pegasus III, July 30 To furnish information on the meteoroid hazard to spacecraft.	Saturn I (SA-10).	ETR	Supplied new data on this danger to aid designers of manned spacecraft for long-duration flights. (Apogee—333.05 miles; Perigee—318.14 miles.)
Scout Evaluation Vehicle (SEV-A), Aug. 10. Flight-qualify and demonstrate major new components of the Scout launch vehicle; orbit the SECOR V geodetic satellite for the Army.	Scout	WI	Scout performed excellently in its test flight, including the new motors in 2d and 4th stages and new spacecraft separation system. The satellite continues on orbit satisfactorily.
Centaur (AC-6), Aug. 11 Vehicle development.	Atlas-Centaur	ETR	4th successful launch of this vehicle. Injected 2,084-lb. dynamic model of Surveyor spacecraft into simulated lunar transfer trajectory. Demonstrated capability of the vehicle to launch Surveyor spacecraft. Represented completion of the 1st phase of Centaur development.
Gemini V, Aug. 21-29 8-day mission of Astronauts L. Gordon Cooper, Jr., and Charles Conrad, Jr.	Modified Titan II.	ETR	Spacecraft functioned in the space environment for a period equal to that of the Apollo lunar mission. Astronauts showed no significant or lasting effects from the trip. 1st Gemini use of the fuel cell. Successful simulated rendezvous.
OSO-C, Aug. 25 Planned as a 3d Orbiting Solar Observatory.	Thor-Delta	ETR	Failed to orbit, apparently due to the premature ignition of the vehicle's 3d stage.
OGO-II (Orbiting Geophysical Observatory II), Oct. 14, Geophysical observations close to the earth and in the upper atmosphere.	Thor-Agena	WTR	Placed in polar orbit (Apogee—941.38 miles; Perigee—239.73 miles) for daily observations over practically the entire globe. Stabilization was lost about Oct. 24, but transmission continued since power was available.
Explorer XXIX, Nov. 6 NASA's 1st satellite devoted entirely to geodetic (earth-mapping) studies, launched as part of a coordinated U.S. geodetic program involving NASA and the Departments of Commerce and Defense.	Improved Thrust-Augmented Delta.	ETR	Satellite's 5 systems of instruments supply more precise data for use in mapping long distances and analyzing geophysical problems. (Apogee—1414.24 miles; Perigee—692.83 miles.)

See footnote at end of table.

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## Major NASA Launches—Continued

(July 1–December 31, 1965)

Name, date launched, mission	Vehicle	Site <sup>1</sup>	Results
Gemini VI (target vehicle), Oct. 25. Rendezvous and docking capability development for manned space flight.	Atlas-Agena	ETR	Gemini VI spacecraft was not launched. When launched, target vehicle failed to achieve orbit. Agena apparently exploded at initiation of 1st burn.
Explorer XXX, Nov. 19. To measure and monitor solar X-ray emissions during the final portion of the 1964–65 International Quiet Sun Year.	Scout	WI	A solar radiation satellite built by the Naval Research Laboratory, it continues solar investigations of the Laboratory begun in 1949. (Apogee—553.64 miles; Perigee—436.20 miles.)
Alouette II Explorer XXXI (dual launch), Nov. 29. Alouette II—2d Canadian satellite—and Explorer XXXI to make related ionospheric studies while orbiting close together.	Thor-Agena B.	WTR	Alouette II extended to polar regions topside ionospheric soundings begun by Alouette I. 8 experiments of Explorer XXXI were correlated with the 5 of the 2d Alouette. (Apogee: Alouette—1855.41 miles; Explorer—1850.44 miles. Perigee of both satellites—313.79 miles.)
Gemini VII, Dec. 4–18. Demonstrate manned orbital flight for a 14-day period; serve as target vehicle for rendezvous attempt.	Modified Titan II.	ETR	Spacecraft set a world's record when it travelled over 5 million miles while flying 330 hours, 35 minutes. Preliminary medical examinations showed Astronauts Frank Borman and James A. Lovell suffered no ill effects from prolonged weightlessness.
FR-1, Dec. 6. 1st satellite launched in a French-American cooperative program of ionospheric and electron studies.	Scout	WTR	The French-built satellite, in a nearly circular orbit (Apogee—467.89 miles; Perigee 465.41 miles), is supplying data on very low frequency (VLF) radio wave phenomena and electron densities.
Gemini VI, Dec. 15–16. Perform space rendezvous within a few feet of the target vehicle, Gemini VII.	Modified Titan II	ETR	Astronauts Walter M. Schirra, Jr. and Thomas P. Stafford carried out the 1st piloted rendezvous beginning in their 2d revolution.
Pioneer VI, Dec. 16. To begin a program to systematically measure and monitor interplanetary space during a complete solar cycle. (Data to be collected from as far away as 50 million miles.)	Improved Thrust-Augmented Delta.	ETR	Spacecraft measured magnetic fields, solar plasma, energetic particles, and electron density.

<sup>1</sup> ETR=Eastern Test Range, Cape Kennedy, Fla.

WI= Wallops Island, Va.

WTR= Western Test Range, Point Arguello, Calif.

## Appendix O

### NASA Launch Vehicles

Vehicle	Stages	Payload in pounds			Principal use
		345-mile orbit	Escape	Mars/Venus	
Scout.....	4	150 to 220.....			Launching small scientific satellites and probes (Explorer XXX, SERT ION engine, SECOR V, French-built FR-1).
Delta.....	3	800.....	120		Launching scientific, meteorological, and communications satellites TIROS IX, Orbiting Solar Observatories—OSO I and II, Ariel, Telstar I, Relay, Syncor II, Interplanetary Monitoring Platforms (Explorers XXI and XXVII), Energetic particles satellite (Explorer XXVI).
Thrust Augmented Delta (TAD). .	3	1,000.....	150	120	Launching scientific, meteorological, communications, and bioscience satellites, and lunar and planetary probes (Pioneer VI, TIROS K, TIROS operational satellites OT-3 and OT-2, Syncor III, Commercial Communications Satellite Early Bird I, Biosatellites C—F).
Thor-Agena B.....	2	1,600.....			Launching scientific, communications, and applications satellites (Echo II, Nimbus I, Polar Orbiting Geophysical Observatory, Orbiting Geophysical Observatory II).
Thrust Augmented Thor-Agena (TAT). .	2	2,200.....			Launching geophysics and astronomy and applications satellites (OGO C, D, and F, and Nimbus B).
Atlas-Agena B.....	2½	5,000.....	750	400	Launching heavy scientific satellites, and lunar and planetary probes (Rangers VII, VIII and IX, Mariners III and IV, Orbiting Geophysical Observatory—OGO-I).
Atlas-Centaur.....	2½	8,500.....	2,300	1,300	Launching heavy unmanned spacecraft as lunar soft landers (Surveyor).
Atlas D.....	1	(1).....			Launched manned Mercury spacecraft.
Modified Titan II.....	2	7,000, 87/161 elliptical orbit.			Launching unmanned and manned Gemini spacecraft.
Saturn I.....	2	20,000 (15,000 without re-start capability).			Orbiting Pegasus I and II spacecraft to detect and report on meteoroid collisions, and launching Project Apollo spacecraft.
Saturn IB.....	2	28,500.....			Launching Project Apollo spacecraft.
Saturn V.....	3	220,000.....	95,000	70,000	Do.

<sup>1</sup> Only NASA application Project Mercury—2,500 pounds in 114-mile orbit.

## Appendix P

**NASA International Activities Summary**  
(Cumulative through December 31, 1965)

Location <sup>1</sup>	Cooperative projects						Operations support (tracking and data acquisition networks)						Personnel exchanges					
	Flight projects		Ground-based projects for—				Scientific satellite experiments		Manned flight		Optical space		Data acquisition		Resident research-associate-relationships	International fellowships	Training at centers	Visits
	Satellites	Experiments on NASA satellites	Meteorological sounding rockets	Communications satellites	Iono-spheric satellites	Solar eclipse experiments			X	X	X	X	X	X	X	X	X	
Argentina																		
Ascension Island																		
Australia																		
Austria																		
Belgium																		
Bermuda																		
Bolivia																		
Brazil																		
Burma																		
Canada	X																	
Canton Island (United Kingdom)																		
Ceylon																		
Chad																		
Chile																		
China, Republic of																		
Colombia																		
Costa Rica																		
Czechoslovakia																		
Denmark		X	X															

See footnotes at end of table.

## NASA International Activities Summary—Continued

Location <sup>1</sup>	Cooperative projects				Operations support (tracking and data acquisition networks)				Personnel exchanges		
	Flight projects		Ground-based projects for—						Resident research associate-ships	International fellowships	Training at centers
	Satellites	Experiments on NASA sounding rockets	Meteorological	Communications	Iono-spheric	Satellite	Manned flight	Deep space	Optical	Moon-watch	Data acquisition
Senegal							X		X	X	
South Africa			X					X	X		
Spain			X		X						X
Sudan			X		X						X
Sweden			X		X						X
Switzerland			X		X						X
Tanzania						X					X
Thailand			X		X						X
Turkey											X
United Arab Republic			X								X
United Kingdom	X	X	X	X	X	X					X
Uruguay											X
U.S.S.R.	(?)										X
Zambia											X
ESRO <sup>2</sup>	X										X
Total	6	4	17	42	12	35	4	8	9	4	28
								10	32	4	17
											18
											3 121

<sup>1</sup> Includes countries, separate jurisdictions and ESRO (Belgium, Denmark, France, Germany, Federal Republic of Italy, Netherlands, Spain, Sweden, Switzerland, United Kingdom).

<sup>2</sup> Agreements provide for: (1) Cooperative communications satellite experiments via Echo II, (2) coordinated launches of national meteorological satellites and data exchange, (3) launches of national satellites equipped for magnetic measurements and exchange of processed data, and (4) joint review of space biology and medicine.

<sup>3</sup> The following, included in the total, participated in the visitor program only:

Afghanistan, Algeria, Barbados, British Guiana, Burundi, Cameroon, Central African Republic, Congo (Leopoldville), Cyprus, Dahomey, Dominican Republic, Dubai, E.D.D.O., Gabon, Gambia, The, Guatemala, Guinea, Haiti, Honduras, Ivory Coast, Jordan, Kuwait, Laos, Lebanon, Liberia, Libya, Lithuania, Luxembourg, Malawi, Malaysia, Mali, Malta, Mauritania, Morocco, Nepal, Nicaragua, Niger, Panama, Paraguay, Rwanda, Saudi Arabia, Sierra Leone, Somalia, South Vietnam, Swaziland, Syria, Togo, Trinidad, Tunisia, Uganda, Upper Volta, Venezuela, Yemen, and Yugoslavia.

## Appendix Q

### Grants and Research Contracts Obligated <sup>1</sup>

July 1-December 31, 1965

#### ALASKA:

NsG-406-----	University of Alaska, W. B. MURCRAY-----	\$12, 006
S 2	Experimental Studies of Auroral Phenomena Including Particulate Fluxes by Means of Rocket-Borne Experiments.	

#### ARIZONA:

NsG-120-----	University of Arizona, R. W. G. WICKOFF-----	50, 222
S 4	Generation and Detection of Ultra-Long Wavelength X-Rays and Quantitative Studies of Their Interactions With Matter.	
NsG-490-----	University of Arizona, L. E. WEAVER-----	11, 081
S 2	Research in and Application of Modern Automatic Control Theory to Nuclear Rocket Dynamics and Control.	
NsG-580-----	University of Arizona, T. L. VINCENT-----	13, 398
S 1	A Study of the Calculus of Variations, Especially as Related to Aerospace Engineering Problems.	
NASr-138-----	University of Arizona, A. M. J. GEHRELS-----	49, 980
A 4	Photo-Polarimeter for Space Vehicles.	

#### CALIFORNIA:

NsG-40-----	California Institute of Technology, H. W. LIEPMANN.	130, 000
S 4	Investigations of Rarefied Gas Flow.	
NsG-172-----	California Institute of Technology, W. G. KNAUSS AND M. L. WILLIAMS.	64, 600
S 5	Investigation of Failure Criteria for Viscoelastic Materials.	
NGR 05-002-040-----	California Institute of Technology, R. B. KING.	29, 090
	Measurement of Oscillator Strengths of Lines in the Spectra of Atoms and Ions.	
NSR 05-002-050-----	California Institute of Technology, H. S. BROWN.	25, 000
	JPL-California Institute of Technology—"Lunar and Planetary Conference."	
NsG-243-----	University of California (Berkeley), S. SILVER-----	79, 000
S 4	Interdisciplinary Space-Oriented Research in the Physical, Biological, Engineering, and Social Sciences.	
NsG-274-----	University of California (Berkeley), E. P. POPOV AND J. PENZIEN.	40, 500
S 2	Investigation of Stresses and Deformations in Thin Shells of Revolution.	

<sup>1</sup>The grants listed are reported to the Congress in compliance with the requirements of the Grant's Statute, 42 U.S.C. 1891-1893 (72 Stat. 1793).

NOTE: Contracts have prefixes NAS and NSR; grants have prefixes NsG and NGR; transfer of funds to Government agencies have prefix R. Earlier grants and contracts are listed in appendices of previous NASA Semiannual Reports to Congress.

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**CALIFORNIA—Continued**

NsG-479----- S 2	University of California (Berkeley), T. H. JUKES. The Chemistry of Living Systems.	\$400, 000
NsG-513----- S 2	University of California (Berkeley), N. PACE— Primate Hemodynamics and Metabolism Under Conditions of Weightlessness, for the Purpose of Defining and Verifying an Experiment Suitable for Use in Biosatellite.	250, 000
NsG-704----- S 1	University of California (Berkeley), A. D. MCCLAREN. An Investigation of Enzyme Assay Techniques for Life Detection in Extra-terrestrial Soils.	13, 424
NSR 05-003-100----- A 1	University of California (Berkeley), A. E. WHITFORD. Development of Low Noise Photomultiplier Tubes for Astronomical Applications.	17, 800
NGR 05-003-080----- S 1	University of California (Berkeley), R. N. COLWELL. Multispectral Photographic Terrain Analyses, Based on Statistical Analysis of Spectrometric Data.	63, 787
NGR 05-003-068----- S 2	University of California (Berkeley), S. MARGEN. Clinical Nutritional Study of Minimal Protein and Caloric Requirements.	152, 526
NASr-220----- A 2	University of California (Berkeley), M. CALVIN AND S. SILVER. Scanning System for Mariner Space Vehicle.	74, 850
NsG-237----- S 6	University of California (Los Angeles), W. F. LIBBY AND J. D. FRENCH. Interdisciplinary Space-Oriented Research in the Physical, Biological, and Engineering Sciences.	190, 800
NsG-502----- S 2	University of California (Los Angeles), J. D. FRENCH AND W. R. ADEY. Neurophysiological and Behavioral Studies of Chimpanzees, Including Establishment of a Group of Implanted Animals Suitable for Space Flight.	120, 000
NGR 05-007-046-----	University of California (Los Angeles), L. H. ALLER. Solar Elements, Their Physical Parameters and Abundances.	48, 182
NsG-541----- S 2	University of California (San Diego), H. C. URBY AND B. NAGY. Analysis of the Organic and Inorganic Constituents of Carbonaceous and Other Se- lected Stony Meteorites.	48, 500
NsG-541----- S 3	University of California (San Diego), H. C. URBY AND B. NAGY. Analysis of the Organic and Inorganic Constituents of Carbonaceous and Other Se- lected Stony Meteorites.	11, 109
NASr-116----- A 7	University of California (San Diego), C. E. MCILWAIN. Conduct Analytical, Theoretical, and Ex- perimental Studies of Geomagnetically Trapped Particles.	27, 000
NASr-116----- A 8	University of California (San Diego), C. E. MCILWAIN. Conduct Analytical, Theoretical, and Ex- perimental Studies of Geomagnetically Trapped Particles.	37, 500

NGR 05-035-003-----	Institute for Lipid Research, C. ENTENMAN-- Study of Body Energy Conservation, Emphasizing Space Flight Environmental Effects on Organisms.	\$58, 614
NsG-289----- S 3	Institute for Medical Research, C. M. AGRESS-- A Study of Measurement Techniques for Determining Cardiac Performance, Including Consideration of Methods for Vibrocardiogram Interpretation, and of Physiological Stress Effects on Man.	78, 120
NASr-21(02)----- A 8	Rand Corp., J. L. HULT----- Studies of Operational and Technological Factors of Communication Satellites.	350, 000
NASr-21(05)----- A 3	Rand Corp., E. H. VESTINE----- Research on Charged Particles and Fields in Space.	199, 144
NsG-331----- S 3	Stanford University, A. SCHAWLOW----- Spectroscopic Studies in Infrared and Optical Quantum Electronics.	100, 000
NsG-582----- S 3	Stanford University, R. H. CANNON, Jr.----- Investigations, Theoretical, and Experimental Analyses for a Zero-G Satellite Development, and Schiff Gyro Test of General Theory of Relativity.	90, 000
NsG(F)-33-----	Stanford University, W. R. RAMBO----- Construction of Research Facilities.	2, 080, 000
NGR 05-020-102-----	Stanford University, K. KARAMCHETI----- Theoretical Studies of Some Nonlinear Aspects of Hypersonic Panel Flutter.	21, 203
NGR 05-020-121-----	Stanford University, R. L. HUNTER----- Study of the Combined Stresses of Radiation and Altered Oxygen Tension on Serum Protein and Enzyme Levels.	29, 514
R 05-038-001-----	U.S. Navy-Pacific Missile Range, F. WHITTENBURG.  Install Precision Instrument No. PI-200 Tape Deck, Special Reel, Universal Mounting Board and Megacycler in PMR Safety Van, and Make Available to UCLA for Ionosphere Disturbance Experiments.	3, 000

## COLORADO :

NsG(F)-32-----	University of Denver, C. M. ALTER----- Construction of a Space Sciences Laboratory.	900, 000
R-18----- A 3	U.S. National Bureau of Standards, F. E. ROACH.  Conduct Investigations in Low Latitude Airglow.	50, 000
R-45----- A 7	U.S. National Bureau of Standards, A. F. SCHMIDT.  Investigations and Research on Cryogenic Properties and Processes.	450, 000
R-133----- A 2	U.S. National Bureau of Standards, W. CALVERT.  Investigation in the Ionosphere with a Multiple Ionospheric Probe.	20, 000
R-110----- A 1	U.S. National Bureau of Standards, W. H. CAMPBELL.  Collection of 3 Component Geomagnetic Micropulsation Data, Digitalization of the Data, and Distribution to NASA Supported Investigators.	97, 000

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COLORADO—Continued			
R-148-----	U.S. National Bureau of Standards, J. W. WRIGHT.		\$5, 200
A 1	Conduct Ionospheric Soundings from a Mobile Launch Platform.		
R 06-006-037-----	U.S. National Bureau of Standards, J. W. WRIGHT.	31, 800	
	Study of Real-Time Height Profiles of Electron Density and Wind Velocity From Ionospheric Radio Soundings.		
NASr-185-----	University Corporation for Atmospheric Re- search, A. L. MORRIS.	250, 000	
A 2	Development of Improved Means of Scienti- fic Ballooning and Conduct Scientific Balloon Flights.		
NASr-213-----	Western State College of Colorado, T. D. VIOLETT.	36, 000	
A 1	Develop and Fly a Rocket Spectrograph to Examine in Close Detail the Solar Spectral Emission in the Neighborhood of the Lyman- Beta Line.		
CONNECTICUT:			
NGR 07-004-034-----	Yale University, A. L. McALESTER AND C. MACCLINTOCK.	72, 000	
	Study of Relationship, Through Geologic Time, of Days per Lunar Month of Growth Increments in Fossil and Recent Molluscan Shells.		
NGR 07-004-039-----	Yale University, S. P. CLARK----- Apollo Lunar Heat Flow Studies.	32, 400	
NGR-07-004-043-----	Yale University, R. WOLFGANG----- Chemical Reactions in the Electron-Volt Region.	61, 200	
DISTRICT OF COLUMBIA:			
NsG-425-----	George Washington University, D. S. WATSON----- S 1	80, 000	
	Statistical and Analytical Investigation of the Relation Between Government Financed Research and Development and Resultant Inventions and of the Special Features of the Government Procurement Market and Contract Provisions That May Affect the National Economy.		
NsG-485-----	George Washington University, C. W. SHIL- LING.	25, 000	
S 3	Scientific Communication Research in Space Biology.		
NSR 09-010-021-----	George Washington University, A. M. ROTH- ROCK.	4, 500	
	Lectures on the Exploration of Space.		
NSR 09-012-901-----	National Academy of Sciences, C. LAPPT----- A 3	1, 550, 000	
	NASA-National Academy of Sciences Resi- dent Research Associates Program.		
NSR 09-012-905-----	National Academy of Sciences, L. SLACK----- Partial Support of Third International Congress of Radiation Research.	10, 000	
NsG 87-----	Smithsonian Institution, F. L. WHIPPLE----- S 14	198, 450	
NsG 87-----	Smithsonian Institution, F. L. WHIPPLE----- S 15	5, 138, 419	
NsG 536-----	Smithsonian Institution, F. L. WHIPPLE----- S 3	52, 195	
	Optical Satellite Tracking Program.		
	Optical Satellite Tracking Program.		
	Optical and Radar Investigations of Simu- lated and Natural Meteors.		

## APPENDIX Q

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NGR 09-015-023-----	Smithsonian Institution, C. SAGAN----- Selected Studies in Exobiology, Planetary Environments and Problems Related to the Origin of Life.	\$134,684
NGR 09-015-025-----	Smithsonian Institution, F. A. FRANKLIN----- Photoelectric Techniques for Measurement of Earthshine.	14,589
R-104(01)----- A 2	U.S. Atomic Energy Commission, E. P. BLIZARD.  Space Vehicle Shielding Studies.	420,000
R-104(02)----- A 3	U.S. Atomic Energy Commission, C. A. TOBIAS----- Studies of Heavy Ionizing Particles and Space Biology.	286,000
R-104(02)----- A 4	U.S. Atomic Energy Commission, C. A. TOBIAS----- Biological Research of the Effects of Proton and Other Irradiation of Different Biological Organisms; Magnetic Protection Against Radiation; and Vibration Combined With Radiation.	200,000
R-104(03)----- A 2	U.S. Atomic Energy Commission, A. HOLLAENDER.  Research on Biological Effects of Proton and Other Radiation, Especially Directed Toward Development of Biosatellite Experiments.	150,000
R-104(04)----- A 2	U.S. Atomic Energy Commission, M. A. BENDER.  Human Blood Irradiation Experiments in Conjunction With the Gemini Mission.	211,000
R-104(05)----- A 2	U.S. Atomic Energy Commission, S. A. GORDON.  Study of Effect of Gravitational, Magnetic and Electrical Fields on Plants.	75,000
R-104(09)----- A 2	U.S. Atomic Energy Commission, G. A. ANDREWS.  Retrospective Study of Radiation Effect.	315,000
R-106----- A 1	U.S. Atomic Energy Commission, W. BRANDT----- Reimbursement for Computer Services.	216
R 09-038-002-----	U.S. Department of Agriculture----- Participation in the NASA Manned Earth-Orbital Space Program.	847,000
R 09-020-011-----	U.S. Department of Interior (Geological Survey), W. T. PECORA.  Geoscience Applications—Manned Earth Orbital Program.	550,000
R 09-020-013----- A 1	U.S. Department of Interior (Geological Survey), L. CLARK.  Remote Terrain Sensing.	300,000
R 09-020-013----- A 2	U.S. Department of the Interior (Geological Survey), L. CLARK.  Remote Terrain Sensing.	33,000
R 09-020-015-----	U.S. Department of the Interior (Geological Survey), W. T. PECORA.  Conduct an Evaluation of Multispectral Sensed Data From Geological, Lunar Analog and Planetary Analog Test Sites.	500,000
R 09-020-019-----	U.S. Department of the Interior (Geological Survey), R. G. REEVES.  Investigate Techniques for Radar Exploration and Analysis of Geologic Phenomena.	60,000
R-141----- A 3	U.S. Library of Congress, P. L. BERRY----- Literature Abstracts in the Field of Aerospace Medicine.	82,000

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<b>DISTRICT OF COLUMBIA—Continued</b>		
R-14-----	U.S. National Bureau of Standards, J. A. BENNETT.	\$28,000
A 5	Room-Temperature Fatigue Tests of Ti-4Al-4Mn, Ti-6Al-4V, and 4340 Steel Are To Be Made in Moist and Dry Oxygen Atmospheres.	
R-51-----	U.S. National Bureau of Standards, G. SCHUBAUEER.	170,000
A 2	Fundamental Experimental Research on the Mechanisms Which Indicate Boundary Layer Transition From Laminar to Turbulent Flow.	
R-56-----	U.S. National Bureau of Standards, L. A. WALL.	35,000
A 4	Investigation of the Effects of Vacuum Ultraviolet Radiation (1,000°-2,000° A.) and of Ionizing Radiation on Polymers in the Temperature Range From Ambient to 500° C.	
R-130-----	U.S. National Bureau of Standards, H. L. LOGAN.	55,000
A 1	A Study of the Mechanism of Stress-Corrosion of Titanium Alloys.	
R-138-----	U.S. National Bureau of Standards, G. T. ARMSTRONG.	32,000
A 1	Study of the Thermodynamic Properties of Molecular Complexes of the C-H-O-N-S-P System.	
R 09-022-039-----	U.S. National Bureau of Standards, J. A. CUNNINGHAM.	50,000
A 1	Research and Development in Selected Areas of Computer Sciences and Related Disciplines.	
R 09-022-052-----	U.S. National Bureau of Standards, A. BRENNER.	23,000
	Investigate the Electrolysis of Solid Salts and Ceramic Materials by Connecting the Materials to the Positive Pole of a Current Source, and Then Subjecting the Materials to an Electron Beam in a Vacuum.	
R 09-136-001-----	U.S. Navy-Naval Oceanographic Office----- Identification of Oceanograph Marine Technology Experiments Utilizing Manned Orbiting Space Stations With Existing or Modified Apollo Hardware.	900,000
R-107-----	U.S. Navy-Naval Research Laboratory, H. FRIEDMAN.	120,000
A 1	Research on Helios Design Studies.	
R 09-029-046-----	U.S. Navy-Naval Research Laboratory, M. H. SCHRENK.	45,000
	Support of the Shock and Vibration Information Center.	
R 09-032-005-----	U.S. Weather Bureau, B. F. LOVELESS----- Partial Support of a Study of the Economic, Operational, and Scientific Benefits of Extension of Meteorological Satellite Capabilities.	50,000
<b>FLORIDA:</b>		
NGR 10-004-029-----	Florida State University, R. G. CORNELL----- Space-Related Biostatistical Studies, Emphasizing Microbiology and Sterilization.	38,928

NsG-67----- S 2	University of Florida, E. E. MUSCHLITZ----- Theoretical and Experimental Investigations of Surface Ionization Processes, Paying Particular Attention to the Formation of O-, O <sub>2</sub> -, and Alkali Metal Ions.	\$10,000
NsG(F)-30-----	University of Florida, L. E. GRINTER----- Construction of Research Laboratory Facilities To Be Known as the Space Sciences Building.	1,190,000
NASr-176----- A 2	University of Florida, A. G. SMITH----- Development of an Orbital Receiver for Low-Frequency Radio Energy From the Planet Jupiter.	36,008
NGR 10-007-028-----	University of Miami, S. F. SINGER----- Research in Atmospheric Measurement Techniques.	49,635
R-93----- A 3	U.S. Navy-Naval School of Aviation Medicine, A. GRAYBIEL.  Investigate the Physiological and Psychological Effects of Gravitational and Inertial Forces on Man in a Manner Which Extends Man's Basic Knowledge of the Area and Simultaneously Applies This Knowledge to Operational Problems.	250,000
R 10-009-013----- A 1	U.S. Navy-Naval School of Aviation Medicine, A. GRAYBIEL.  Research in Subhuman Primates in Long Duration Orbital Flight With Rendezvous Recovery Nos. 1, 2, 3, 4, 5, and 10	158,860
<b>GEORGIA:</b>		
NGR 11-001-012----- S 1	Emory University, B. W. ROBINSON----- Study of Control and Analysis of Primate Behavior by Brain Teletimulation and Telemetry.	105,772
NsG-273----- S 3	Georgia Institute of Technology, C. ORR----- Heat Transfer to a Gas Containing a Cloud of Particles.	30,000
NsG-571----- S 1	Georgia Institute of Technology, J. T. WANG----- A Study of Differential Equations Related to the Response of Shells of Revolution to Blast Loading.	19,864
R-137----- A 1	U.S. Department of Health, Education, and Welfare, S. W. SIMMONS.  Research on Microbiological Sterilization Problems.	206,000
R-137----- A 2	U.S. Department of Health, Education, and Welfare, S. W. SIMMONS.  Research on Microbiological Sterilization Problems.	99,000
<b>HAWAII:</b>		
NGR 12-001-010----- S 1	University of Hawaii, T. A. ROGERS----- Study of Body Fluid Volume and Electrolyte Derangements in Fasting.	14,360
NGR 12-001-011----- S 1	University of Hawaii, J. T. JEFFRIES----- Research in Coronal and Chromospheric Physics.	484,000
<b>ILLINOIS:</b>		
NsG-333----- S 2	University of Chicago, T. FUJITA----- Meteorological Interpretation of Satellite Radiation Data.	53,210
NsG-467----- S 1	University of Chicago, C. O. HINES----- A Theoretical Investigation of Upper Atmosphere Dynamics, Including the Effects of Tidal Oscillation, Large Scale Circulation, and Smaller Scale Random Motions.	83,574

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<b>ILLINOIS—Continued</b>			
NSR 14-001-059-----	University of Chicago, J. A. SIMPSON-----	\$70, 591	
	Reduction and Preliminary Analysis of Pioneer Spacecraft Experiment Data.		
NASr-22-----	IIT Research Institute, E. J. HAWRYLEWICZ----	29, 952	
A 5	Life in Extraterrestrial Environments.		
NASr-65(03)-----	IIT Research Institute, L. CONROY-----	50, 345	
A 6	Evaluation of Technological Developments Resulting From the Nation's Space Effort.		
NASr-65(06)-----	IIT Research Institute, C. A. STONE-----	450, 000	
A 6	Conduct Studies and Analyses of Space Science Problems Related to the Planning and Directing of NASA Lunar and Planetary Programs.		
NASr-65(08)-----	IIT Research Institute, W. M. LANGDON----	85, 066	
A 1	Backstreaming From Oil Diffusion and Turbo-Molecular Pumps.		
NASr-65(09)-----	IIT Research Institute, C. W. BOQUIST----	94, 856	
A 1	Evaluate the Properties of Graphite Metal Alloys.		
NASr-65(10)-----	IIT Research Institute, C. A. STONE-----	127, 540	
A 2	Conduct Scientific and Engineering Studies Related to Manned Space Science Problems.		
NsG-280-----	University of Illinois, J. H. BARTLETT-----	21, 013	
S 1	Theoretical Research on the Periodic Motion and Stability of a Small Mass Under the Gravitational Attraction of Two Heavy Bodies.		
NsG-395-----	University of Illinois, R. MITTRA-----	45, 000	
S 2	A Study of Selected Radiation and Propa- gation Problems Related to Antennas and Probes in Magneto-Ionic Media.		
NsG-434-----	University of Illinois, W. J. WORLEY-----	33, 703	
S 2	Study of Line Integrals, Surface Integrals, Volumes, Centroids, and Moments of Inertia for a Class of Shells of Revolution and for a Larger Class of Shells.		
NsG-511-----	University of Illinois, S. A. BOWHILL-----	215, 000	
S 2	Investigation of the D and E Regions of the Ionosphere by Ground and Rocket Methods.		
NGR 14-005-037-----	University of Illinois, L. GOLDSTEIN-----	40, 000	
S 1	Investigation of Basic Processes Occurring in Gaseous Plasmas in Various Charge Den- sity and Energy States.		
NGR 14-005-048-----	University of Illinois, B. T. CHAO-----	44, 693	
	Transient Thermal Modeling of Space- craft.		
NGR 14-005-050-----	University of Illinois, R. E. JOHNSON-----	38, 090	
	Investigation of Properties of Human Sweat and Factors Affecting the Water Bal- ance in Confined Spaces.		
NGR 14-005-074-----	University of Illinois, H. W. ADES-----	42, 300	
	Physiological Responses of Central Vestib- ular Pathways and Diffuse Ascending Sys- tems to Vestibular Stimulation.		
NGR 14-012-002-----	University of Illinois, E. F. MASUR-----	21, 957	
	Asymptotic Behavior and Collapse of Buckled Plates Shells.		
NGR 14-012-003-----	University of Illinois, J. P. HARTNETT-----	30, 000	
	Mass Transfer Cooling in Nitrogen and Carbon Dioxide Gas Streams.		

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NsG-24----- S 6	University of Illinois, G. W. SWENSON, Jr.----- Experimental and Theoretical Studies of Ionospheric Electron Control and Irregularities.	76, 800
NsG-195----- S 3	University of Illinois, W. J. FRY----- Experimental Analysis of the Micro-Neuroanatomy of the Central Nervous System.	225, 000
NsG-495----- S 1	Northwestern University, A. H. RUBENSTEIN----- Studies and Analyses of Problems Relating to the Management of Scientific Research and Development.	110, 000
NGR 14-007-027----- S 1	Northwestern University, E. H. T. WHITTEN----- Statistical Evaluation of the Chemistry, Mineralogy and Rock Types of Selected Test Sites and Their Relationship to Remotely Sensed Data.	125, 244
NSR 14-007-037-----	Northwestern University, A. B. CABEL----- Partial Support for Sixth Biennial Gas Dynamic Symposium.	2, 000
NGR 14-008-003----- S 1	Southern Illinois University, G. H. GASS----- Effect of Chronic Restraint on Absorption From the Gastrointestinal Tract.	36, 906
<b>INDIANA:</b>		
NsG-553----- S 2	Purdue University, J. C. HANCOCK----- Theoretical and Experimental Studies of Sub-Optimal Second and Third Generation Self Adaptive Binary Communication Systems.	50, 000
<b>KANSAS:</b>		
NGR 17-003-003----- S 1	Wichita State University, W. H. WENTZ----- Investigation of Flow Fields About Delta and Double-Delta Wings of Low Speeds.	48, 028
<b>KENTUCKY:</b>		
NsG-393----- S 2	University of Kentucky, W. G. KROGDAHL----- Determination of Wave Function of Two- Electron Systems.	19, 691
NGR 18-001-008----- S 1	University of Kentucky, R. E. SMITH----- Study of Circadian Rhythms in Primates as Influenced by Latitude, Longitude, Gravity and Confinement.	21, 070
NGR 18-002-008-----	University of Louisville, E. A. ALLUISI----- Performance Measurement of Intellectual Functioning.	34, 064
<b>MARYLAND:</b>		
NsG-189----- S 5	University of Maryland, J. V. BRADY----- Study of the Behavior of Organisms Under Conditions of Space Flight.	58, 877
NsG-566----- S 2	University of Maryland, R. G. GRENNELL----- Neurobiologic Substrates of Behavior.	99, 960
NGR 21-002-040----- S 1	University of Maryland, R. G. GRENNELL----- Study of Protein Hydration in Isolated Cell Surface Structure.	14, 720
NGR 21-002-059-----	University of Maryland, E. R. LIPPINCOTT AND Y. T. PRATT. Investigations on Equilibrium and Non- Equilibrium Systems in Pre-Biological Atmospheres.	84, 000
NGR 21-002-066-----	University of Maryland, J. A. EARL----- A Study of Primary Cosmic Ray Electrons, Utilizing Balloon-Borne Experiments.	70, 000
NSR 21-003-002----- A 1	National Biomedical Research Foundation, M. O. DAYHOFF. A Study of Thermodynamic Properties of Molecular Complexes of Organic Molecular Systems.	42, 000

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<b>MARYLAND—Continued</b>			
R-35----- A 5	U.S. Army Biological Laboratories, C. R. PHILLIPS. Study of Space Vehicle Sterilization Problems.	\$65,000	
R 21-009-004----- A 1	U.S. Navy-Bureau of Naval Weapons, G. WEIFFENBACH AND C. BOSTON. Satellite Data Analysis Including Injun III, 1963 38C, and 1964 38C.	267,000	
R 21-009-014-----	U.S. Navy-Bureau of Naval Weapons, R. B. KERSHNER. Study of Engineering Aspects of Apollo Oriented, Long Duration, Zero G Primate Experiment.	50,000	
R-38----- A 5	U.S. Navy-Naval Medical Research Institute, T. BENZINGER. Research in the Life Sciences on the Energies and Chemistry of Biological Reac- tions, With Emphasis on Energy and Carbon Assimilation.	75,000	
R-63----- A 4	U.S. Navy-Naval Medical Research Institute, H. T. MARYMAN. Experimental Investigation of the Mecha- nism by Which Freezing or Drying and Associated Effects Affect Living Cells, and Investigation of Degradation of Biological Materials in Liquid Nitrogen.	22,884	
NsG-670----- S 1	Woodstock College, J. G. MARZOLF----- Theoretical and Experimental Studies in Planetary and Atmospheric Physics.	40,000	
<b>MASSACHUSETTS:</b>			
NsG-540----- S 2	Brandeis University, J. S. GOLDSTEIN----- Theoretical Studies in Radiative Transfer in Planetary Atmospheres and Rarefied Gases; Related Topics of Astrophysical Interest.	28,875	
NsG-595----- S 1	Harvard University, L. E. EARLEY AND W. H. ABELMAN. A Study of the Physiological Mechanisms and Inter-Relations Between Systemic and Regional Blood Volume, Blood Flow, and Electrolyte Balance.	102,235	
NsG-718----- S 1	Harvard University, R. McFARLAND AND N. MACKWORTH. Human Performance in Adverse Environ- ments.	30,000	
NGR 22-007-053-----	Harvard University, L. SILVERMAN----- Study of Space Cabin Atmospheres.	28,875	
NGR 22-007-054-----	Harvard University, N. F. RAMSEY----- Hydrogen Maser Studies of Relativity.	47,640	
NGR 22-007-056-----	Harvard University, R. W. P. KING----- Theoretical and Experimental Investiga- tions of Antennas and Waves in Plasma.	47,975	
NsG-719----- S 1	Massachusetts General Hospital, M. S. POT- SAID. Study of Solid Chemical Radiation Dosim- eters.	19,740	
NsG-691----- S 1	Massachusetts Institute of Technology, G. SILVERMAN. Study of the Resistivity of Microorga- nisms to Thermal Inactivation by Dry Heat.	38,735	
NGR 22-009-059-----	Massachusetts Institute of Technology, Z. M. ELIAS. Study of Thin Shell Theory.	24,600	

NGR 22-009-091-----	Massachusetts Institute of Technology, R. E. STICKNEY.	\$35,000
S 1	Study of Transport Properties of Thermonuclear Plasmas.	
NGR 22-009-131-----	Massachusetts Institute of Technology, G. FIOCCO.	48,943
	Sensing of Meteorological Variables by Laser Probe Techniques.	
NSR 22-009-106-----	Massachusetts Institute of Technology, P. B. SEBRING.	1,173,000
	Conduct Radar and Radiometric Studies of the Lunar Surface.	
NSR 22-009-120-----	Massachusetts Institute of Technology, A. H. BARRETT.	100,000
	Develop Microwave Imaging and Spectral Systems for Use in Orbiting Spacecraft.	
NGR 22-011-013-----	Northeastern University, SZE-HOU CHANG-----	29,876
	Utilization of Information Theory in Digital Data Guidance Systems.	
<b>MICHIGAN :</b>		
NsG-415-----	University of Michigan, H. C. EARLY-----	14,935
S 2	Theoretical and Experimental Investigations of Extremely Dense Plasmas at Very High Densities.	
NsG-696-----	University of Michigan, J. E. ROWE-----	36,000
S 1	An Investigation of Non-Linear Interaction Phenomena in the Ionosphere.	
NASr-175-----	Wayne State University, R. M. WHALEY-----	300,000
A 1	Program to Accelerate the Industrial Application of Aerospace Related Technology.	
<b>MINNESOTA :</b>		
NsG-327-----	Mayo Foundation, E. H. WOOD-----	14,676
S 4	Studies of the Effects of Acceleration on Cardiovascular and Respiratory Dynamics.	
NsG-643-----	University of Minnesota, G. S. MICHAELSON-----	53,507
S 2	Experimental Investigation of Microbiological Contamination in "Clean Rooms" Emphasizing Factors Relevant to Spacecraft Sterility.	
NsG-714-----	University of Minnesota, R. J. GOLDSTEIN-----	10,000
S 1	Study of Heat Transfer Through Convective Layers.	
NGR 24-005-054-----	University of Minnesota, F. M. SWAIN-----	47,607
	Biochemical Evolution of Pre-Mesozoic Carbohydrates.	
<b>MISSISSIPPI :</b>		
NGR 25-001-007-----	Mississippi State University, J. O. HERBERT, JR.	90,000
	A Study of 2 Gc Region Electromagnetic Propagation Over Selected Terrains.	
NGR 25-001-008-----	Mississippi State University, G. E. JONES-----	54,921
	Microwave Spectroscopic Identification of Atmospheric Contaminants.	
<b>MISSOURI :</b>		
NASr-63(06)-----	Midwest Research Institute, P. BRYANT-----	67,924
A 2	Extreme Vacuum Technology Including Cryosorption Diffusion Pump and Pressure Calibration Studies.	
NGR 26-004-021-----	University of Missouri, X. J. MUSACCIA-----	20,712
	Effects of Radiation on Gastrointestinal Function and Cyclic Turnover of Intestinal Epithelium.	

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<b>MONTANA :</b>			
NGR 27-001-015-----	Montana State University, K. L. NORDTVEDT--	\$9, 960	
	Study of Manual Navigation of Spacecraft.		
NsG-430-----	Montana State University, I. E. DAYTON-----	100, 000	
S 2	Research in Space Science and Engineering.		
<b>NEW HAMPSHIRE :</b>			
NASr-164-----	University of New Hampshire, J. A. LOCKWOOD-	122, 078	
A 5	Measurement of Neutron Intensity in		
	Space.		
<b>NEW JERSEY :</b>			
NsG-69-----	Princeton University, M. SCHWARZSCHILD----	400, 000	
S 8	Stratoscope II High Altitude Balloon		
	Telescope Program.		
NsG-200-----	Princeton University, M. SUMMERFIELD-----	65, 000	
S 4	Ignition, and Combustion Stability and		
	Efficiency, of Solid Propellants at Low		
	Pressures.		
NsG-306-----	Princeton University, R. G. JAHN-----	132, 227	
S 4	Theoretical and Experimental Studies of		
	the Formation and Stability of the Magneto-		
	gasdynamic Front in a Pinch Discharge,		
	Emphasizing Investigations of Electromag-		
	netic Acceleration Processes.		
NGR 31-001-044-----	Princeton University, L. SPITZER-----	110, 000	
S 1	Design Study of Manned Orbiting Tele-		
	scope for an Extended Apollo System.		
NsG-447-----	Rutgers State University, D. A. LUPFER-----	7, 471	
S 2	Studies of Minimum-Thickness Electro-		
	Ceramic Films, Including Relationship of		
	Mechanical and Electronic Properties to		
	Method of Formation.		
NGR 31-003-014-----	Stevens Institute of Technology, R. F.	29, 024	
S 1	MCALEVY III.		
	Investigation of Flame Spreading Over the		
	Surface of Ignited Solid Propellants.		
NGR 31-003-032-----	Stevens Institute of Technology, L. GOLD----	25, 380	
	Theoretical Study of the Red-Shift in		
	Astronomical Observations.		
<b>NEW MEXICO :</b>			
NGR 32-003-027-----	New Mexico State University, J. E. WEISS----	300, 000	
	Multidisciplinary Research Program in		
	Space Science and Engineering.		
NGR 32-004-011-----	University of New Mexico, W. E. ELSTON-----	51, 230	
S 1	Comparative Study of Lunar Craters and		
	Terrestrial Volcano-Tectonic Depressions in		
	Rhyolite Ash-Flow Plateaus.		
<b>NEW YORK :</b>			
NSR 33-003-009-----	American Institute of Aeronautics and Astro-	1, 297, 000	
	nautics, J. J. GLENNON.		
	A Scientific and Technical Information		
	Service, Including Abstracting and Indexing,		
	Covering Published Aerospace Literature.		
NGR 33-006-020-----	Polytechnic Institute of Brooklyn, K. K.	64, 343	
	CLARKE.		
	A Space Communications Study.		
NGR 33-008-039-----	Columbia University, G. SUTTON AND M.	41, 111	
	EWING.		
	Study of Development of a Passive Lunar		
	Seismic System.		
NGR 33-008-059-----	Columbia University, M. G. LANGSETH-----	33, 100	
	Lunar Thermal Measurements in Conjunction		
	With Project Apollo.		

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NGR 33-008-062-----	Columbia University, L. WOLTjer-----	\$32,120
	Experimental Research in Infrared Astronomy.	
NASr-156-----	Cornell Aeronautical Laboratory, Inc., J. W. FORD.	68,475
A 3	Research in "Warm Fog" Dispersal Designed to Improve Airport Utilization.	
NsG-167-----	New York University, S. A. KORFF-----	20,000
S 4	Investigation of Cosmic Rays, Neutrons, and Interplanetary Plasma in the Solar System.	
NsG-683-----	New York University, L. ARNOLD-----	15,000
S 1	Research in Geophysics and Astrophysics.	
NGR 33-016-067-----	New York University, J. R. RAGAZZINI-----	600,000
	Multidisciplinary Research in Space Science and Engineering.	
NsG-261-----	Rensselaer Polytechnic Institute, P. HARTECK-----	50,000
S 2	Chemistry of Planetary Atmospheres and Comets.	
NsG-290-----	Rensselaer Polytechnic Institute, J. C. CORELLI-----	65,800
S 3	Studies of Radiation Damage to Semi-Conductors and Their Metallic Films by High Energy Electron, Proton, and Neutron-Gamma Radiation.	
NsG-371-----	Rensselaer Polytechnic Institute, F. A. WHITE-----	4,980
S 3	Theoretical and Experimental Study of Radiation Damage and Effects on the Properties of Materials.	
NGR 33-018-053-----	Rensselaer Polytechnic Institute, F. A. WHITE-----	75,000
	Techniques for Increasing the Sensitivity of Mass Spectrometric Gas Analyses, Utilizing Ion Detectors.	
NsG(F)29-----	University of Rochester, W. O. FENN-----	1,000,000
	Construction of Research Laboratory Facilities Housing the Space Science Center.	
NGR 33-019-048-----	University of Rochester, H. GAMO-----	25,599
	Study of CW Gaseous Lasers for Optical Communications in Space.	
NGR 33-022-032-----	Syracuse University, H. W. LIU-----	22,500
	Fatigue Crack Propagation and Strains Within Plastic Zone.	
NGR 33-022-035-----	Syracuse University, M. E. BARRELAY-----	42,720
	Gas Radiation and Transport Properties at High Temperatures.	
NsG-489-----	Yeshiva University, S. WEINSTEIN-----	110,486
S 3	Investigations of Effects of Sensory Deprivations of Varying Durations on Sensory, Perceptual, Physiological, Emotional, and Spatial Orientation of the Individual.	
NGR 33-023-009-----	Yeshiva University, G. CARMI-----	22,000
	Study of Propagation of Energetic Particles in Interplanetary Space.	
<b>NORTH CAROLINA:</b>		
NGR 34-002-027-----	North Carolina State University, H. A. HAS-SAN.	27,000
	Theoretical Investigation of Liquid Water Injection Into the Shock Layer of Reentry Vehicle.	
NGR 34-002-032-----	North Carolina State University, H. SAGAN--	33,476
	Mathematical Theory of Optimal Control.	

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**OHIO:**

NsG-110----- S 6	Case Institute of Technology, L. A. SCHMIT, Jr.	\$72, 720
	Application of Structural Synthesis to Aerospace Vehicle Structures.	
NsG-728----- S 1	Case Institute of Technology, H. W. MERR- LER.	66, 220
	Investigation of Control in Man-Machine Systems With Emphasis on Problems of Remote Manipulation.	
NsG(F)28-----	Case Institute of Technology, H. R. NARA----- Construction of Research Facilities.	2, 226, 000
NsG-75----- S 2	University of Cincinnati, B. BLACK-SCHAFFER Study of Protection Against Acceleration by Immersion During a Low Temperature State.	24, 360
NSG 36-004-013-----	University of Cincinnati, R. J. KNOLL----- Investigation of the Longitudinal Vibrations of Liquid Fueled Launch Vehicles.	32, 000
NsG-463----- S 1	Kent State University, J. W. REED----- Theoretical and Experimental Studies of the Magnetic and Molecular Properties of Selected Compounds, Using Neutron Diffrac- tion Techniques.	46, 363
NsG-568----- S 2	Kent State University, T. N. BHARGAVA----- Stochastic Models for Multi-Dimensional, Multi-Valued Relations.	29, 040
NsG-74----- S 5	Ohio State University, C. A. LEVIS----- Research on Receiver Techniques and De- tectors for Use at Millimeter and Submil- limeter Wave Lengths.	75, 000
NsG-448----- S 2	Ohio State University, C. LEVIS----- Theoretical and Experimental Investiga- tions of Spacecraft Antenna Problems in the Varied Operational Environments of Farout Space and Atmospheric Re-Entry.	45, 000
NSR 36-008-027----- A 2	Ohio State University, W. PEAKE----- Conduct an Investigation of Radar and Microwave Radiometric Techniques for Geo- science Experiments Which May Be Carried Out in Manned Orbiting Spacecraft.	180, 382
NGR 36-008-048-----	Ohio State University, R. C. RUDDUCK----- Theoretical and Experimental Studies of Antennas for Reflectometer Application.	40, 000

**OKLAHOMA:**

NsG-300----- S 3	Oklahoma City University, J. P. JORDAN----- Interdisciplinary Studies of the Effects of the Space Environment on Biological Systems.	40, 000
NsG-609----- S 1	Oklahoma State University, C. A. DUNN----- Research in Space-Related Sciences and Engineering.	75, 000
NASr-178----- A 2	Southeastern State College, L. B. ZINK----- Construct a Profile of the Existing Eco- nomic Structure of the Region Surrounding the Southeastern State College.	32, 000
NASr-178----- A 3	Southeastern State College, L. B. ZINK----- Construct a Profile of the Existing Eco- nomic Structure of the Region Surrounding the Southeastern State College.	98, 000

**OREGON:**

NGR 38-002-013-----	Oregon State University, H. CURL, Jr----- Physiological Ecology of Cryophilic Algae.	48, 592
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## PENNSYLVANIA :

NsG-270----- S 3	Drexel Institute of Technology, P. C. CHOU----- Theoretical Analysis of Liquid Filled Fuel Tanks Impacted by Hypervelocity Particles.	\$47,394
NsG-324----- S 3	Pennsylvania State University, E. C. POLLARD----- Study of the Structure and Function of Living Cells.	152,960
NGR 39-009-015-----	Pennsylvania State University, P. EBAUGH----- Research in the Space-Related Sciences and Engineering.	600,000
NsG-416----- S 2	University of Pittsburgh, D. HALLIDAY----- Interdisciplinary Space-Related Research in the Physical, Life and Engineering Sciences.	320,000
NGR 39-011-035-----	University of Pittsburgh, E. GERJUOY----- New Formulas for Collision Amplitudes and Related Quantities.	14,201
NGR 39-023-002-----	Villanova University, G. C. YEH----- Kinetic Study of Electrically Activated Reaction Systems.	15,000

## RHODE ISLAND :

NsG-373----- S 2	Brown University, H. E. FARNSWORTH----- Determination of the Degree of Order Present on Refractory-Metal Single Crystals as Affected by Chemical Etches and Various Heat Treatment.	27,000
NGR 40-002-027-----	Brown University, W. N. FINDLEY----- An Investigation of the Creep and Relaxa- tion of Nonlinear Materials Under Multiaxial Stressing.	81,788

## TENNESSEE :

NGR 43-002-015-----	Vanderbilt University, M. G. BOYCE----- Applications of Calculus of Variations to the Optimization of Multistage Trajectories.	22,657
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## TEXAS :

NASr-198----- A 4	Graduate Research Center of the Southwest, K. G. McCracken. Develop and Evaluate Techniques and In- strumentation for the Measurement of Cosmic Radiation Anisotropies.	130,000
NSR 44-004-017----- A 1	Graduate Research Center of the Southwest, J. A. FEJER AND W. J. HEIKKILA. Design and Construct 5 Ionospheric Probes in each of 3 Nike-Apache Rocket Payloads.	23,488
NSR 44-004-043-----	Graduate Research Center of the Southwest, K. G. McCracken. Processing and Interpretation of Data for Pioneers A and B.	19,186
NGR 44-005-019-----	University of Houston, N. M. SHORT----- Petrographic Analysis of the Anatomy of a Meteorite Impact Crater.	14,739
NGR 44-006-032-----	Rice University, J. W. FREEMAN, JR.----- Feasibility Study of a Detector for the Positive Ion Constituents of the Lunar At- mosphere To Be Employed on the Apollo Lunar Surface Experiments Module.	17,234
NGR 44-006-034-----	Rice University, A. MIELE----- Theoretical Studies of Hypersonic Lifting Bodies.	17,000
NsG-669----- S 1	Texas A. & M. University, A. E. CRONK----- Improvement of Propeller Static Thrust Estimation.	82,878

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**TEXAS—Continued**

NGR 44-001-031-----	Texas A. & M. University, T. J. KOZIK----- The Analysis of Structurally Orthotropic Shells by Means of the Compliance Method.	\$32,752
NsG-440----- S 2	Texas Woman's University, P. B. MACK----- An Experimental Investigation of Skeletal Mineral Losses in Humans and Monkeys.	45,000
R 44-014-014-----	U.S. Air Force—School of Aerospace Medicine, T. H. ALLEN.  Formulate, Evaluate, Design and Compare Foods of 3 General Types From Diverse Sources as Sustaining Human Diets for Extended Aerospace Missions.	25,000

**UTAH:**

NGR 45-003-019-----	University of Utah, N. W. RYAN AND A. D. BAER.  Investigation of the Combustion Chemistry of Composite Rocket Propellants.	67,135
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**VIRGINIA:**

NASr-10----- A 9	Hazleton Laboratories, Inc., G. V. LEVIN----- Radioisotopic Biochemical Probe for Extraterrestrial Life Detection.	59,100
NsG-635----- S 1	University of Virginia, J. W. MOORE----- Analysis and Improvement of Iteration Methods for Solving Automatic Control Equations.	8,850
NGR 47-005-031-----	University of Virginia, L. W. FREDRICK----- Study of the Design and Applications of Interferometers in Earth Orbit.	8,442
NGR 47-005-032-----	University of Virginia, L. W. FREDRICK----- Observations of Lunar Phenomena.	13,681
NGR 47-005-040-----	University of Virginia, G. B. MATTHEWS----- Wind Tunnel Effects in V/STOL Model Testing.	24,788
NsG-636----- S 1	College of William and Mary, H. O. FUNSTEN----- An Investigation of Pion and Muon Beam Transport Systems.	28,152

**WASHINGTON:**

NsG-401----- S 3	University of Washington, R. J. H. BOLLARD AND E. H. DILL.  An Analytical and Experimental Study, Using Photoelastic Methods, to Establish a Procedure for Stress Analysis of a Viscoelastic Model Subjected to Transient Temperature and Time Dependent Loading.	42,163
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**WISCONSIN:**

NGR 50-002-040-----	University of Wisconsin, L. C. YOUNG----- Variational Methods and Their Applications in Optimal Control and in Partial Differential Equations.	10,076
NGR 50-002-044-----	University of Wisconsin, W. L. KRAUSCHAAR--- Research in Cosmic and Solar Physics.	175,000
NGR 50-002-047-----	University of Wisconsin, W. KRAUSCHAAR--- Study of Manned Space Investigations in X and Gamma Ray Astronomy.	13,200

**WYOMING:**

NsG-658----- S 1	University of Wyoming, J. C. BELLAMY----- Orbital Operations Study.	50,000
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**FOREIGN:**

NGR 52-059-001-----	McMaster University, A. B. KRISTOFFERSON--- A Study of Attention and Psychological Time.	26,919
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## APPENDIX Q

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NGR 52-056-001-----	Swiss Federal Institute of Technology, E. STIEFEL.	\$15,000
	A Study of Regularization in Celestial Mechanics.	
NGR 52-026-008----- S 1	University of Toronto, G. K. KORBACHER----- Failure Mechanisms and Statistical As- pects of Metal Fatigue.	17,911
NGR 52-026-011-----	University of Toronto, R. C. TENNYSON----- Buckling of Circular Cylindrical Photo- elastic Shells in Axial Compression.	14,350
NGR 52-061-001-----	University College, A. N. HUNTER----- Partial Support of the World Magnetic Survey Program at Nairobi, Kenya.	3,000

## Appendix R

### Institutions Currently Participating in NASA's Predoctoral Training Program (December 31, 1965)

Adelphia University	Howard University
Alabama, University of	Idaho, University of
Alaska, University of	Illinois Institute of Technology
Alfred University	Illinois, University of
Arizona State University	Indiana University
Arizona, University of	Iowa, University of
Arkansas, University of	Iowa State University
Auburn University	Johns Hopkins University
Baylor University	Kansas State University
Boston College	Kansas, University of
Boston University	Kent State University
Brandeis University	Kentucky, University of
Brigham Young University	Lehigh University
Brooklyn, Polytechnic Institute of	Louisiana State University
Brown University	Louisville, University of
California Institute of Technology	Lowell Technological Institute
California, University of, at Berkeley	Maine, University of
California, University of, at Los Angeles	Marquette University
California, University of, at Riverside	Maryland, University of
California, University of, at San Diego	Massachusetts Institute of Technology
California, University of, at Santa Barbara	Massachusetts, University of
Carnegie Institute of Technology	Miami, University of
Case Institute of Technology	Michigan State University
Catholic University of America	Michigan, University of
Chicago, University of	Michigan Technological University
Cincinnati, University of	Minnesota, University of
Clark University	Mississippi State University
Clarkson College of Technology	Mississippi, University of
Clemson University	Missouri, University of
Colorado School of Mines	Missouri, University of, at Rolla
Colorado State University	Montana State University
Colorado, University of	Montana, University of
Columbia University	Nebraska, University of
Connecticut, University of	Nevada, University of
Cornell University	New Hampshire, University of
Dartmouth College	New Mexico State University
Delaware, University of	New Mexico, University of
Denver, University of	New York, The City University of
Drexel Institute of Technology	New York, State University of, at Buffalo
Duke University	New York, State University of, at Stony Brook
Duquesne University	New York University
Emory University	North Carolina State University, at Raleigh
Florida State University	North Carolina, University of
Florida, University of	North Dakota State University
Fordham University	North Dakota, University of
George Washington University	Northeastern University
Georgetown University	Northwestern University
Georgia Institute of Technology	Notre Dame, University of
Georgia, University of	Ohio State University
Hawaii, University of	
Houston, University of	

Ohio University  
Oklahoma State University  
Oklahoma, University of  
Oregon State University  
Pennsylvania State University  
Pennsylvania, University of  
Pittsburgh, University of  
Princeton University  
Purdue University  
Rensselaer Polytechnic Institute  
Rhode Island, University of  
Rice University  
Rochester, University of  
Rutgers—The State University  
St. Louis University  
South Carolina, University of  
South Dakota, University of  
Southern California, University of  
Southern Illinois University  
Southern Methodist University  
Southern Mississippi, University of  
Stanford University  
Stevens Institute of Technology  
Syracuse University  
Temple University  
Tennessee, University of  
Texas A. & M. University  
Texas Christian University  
Texas Technological College  
Texas, University of  
Toledo, University of  
Tufts University  
Tulane University  
Utah State University  
Utah, University of  
Vanderbilt University  
Vermont, University of  
Villanova University  
Virginia Polytechnic Institute  
Virginia, University of  
Washington State University  
Washington University  
Washington, University of  
Wayne State University  
West Virginia University  
Western Reserve University  
William and Mary, College of  
Wisconsin, University of  
Worcester Polytechnic Institute  
Wyoming, University of  
Yale University  
Yeshiva University

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